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US Army Corps  
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October 1994

# Environmental Assessment and Finding of No Significant Impact (FONSI) of the Underground Technology Program, Rodgers Hollow, Fort Knox, KY

by D. W. Murrell, J. S. Shore

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by D. W. Murrell, J. S. Shore

U.S. Army Corps of Engineers  
Waterways Experiment Station  
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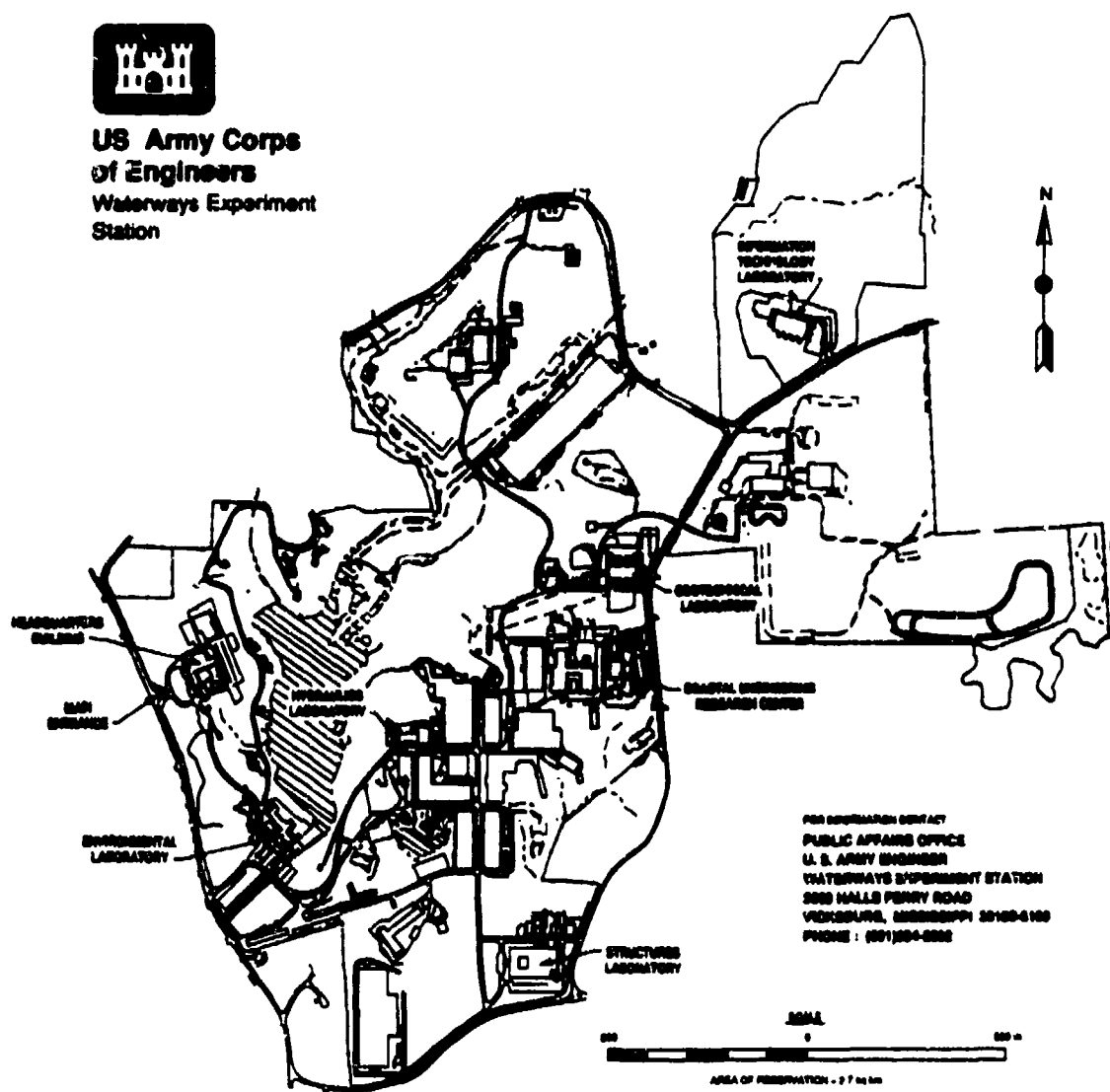
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# Contents

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Preface .....	vi
Conversion Factors, Non-SI to SI (Metric) Units .....	vii
Summary .....	viii
1—Introduction .....	1
Purpose and Need for the Proposed Action .....	1
Description of the Proposed Action .....	1
General .....	1
UTP CAL-2 and CAL-3 .....	3
UTP Large-Scale CAL .....	4
UTP main event .....	4
Construction and testing activities .....	6
The Test Site Environment .....	15
General .....	15
Location of the proposed test site .....	15
Physiography, Geology, and Hydrogeology .....	15
Climate .....	17
Air quality .....	17
Ambient noise level .....	19
Ecology .....	19
Archaeological, historical, and cultural resources .....	21
Other related federal activities .....	21
2—Alternatives To The Proposed Action .....	22
General .....	22
Evaluation of Alternatives .....	23
No action .....	23
Conduct test at other locations .....	23
Reanalysis of existing data .....	23
Reduce the scope of the project .....	23
Simulate in a laboratory .....	25
3—Environmental Consequences of the Proposed Action .....	26
Environmental Consequences of the Proposed Construction .....	26
General .....	26
Air quality .....	27

Noise impact . . . . .	27
Geology and soils . . . . .	27
Ground water quality . . . . .	29
Hazardous materials . . . . .	29
Environmental Consequences of Explosion Phenomena . . . . .	30
General . . . . .	30
Airblast and noise . . . . .	30
Ground shock . . . . .	32
Cratering and ejecta . . . . .	45
Charge cavity and fracture zone . . . . .	45
Detonation products . . . . .	46
Ecological Consequences . . . . .	53
Socioeconomic Consequences . . . . .	53
Geologic Consequences . . . . .	54
Historical, Archaeological, and Paleontological Consequences . . . . .	54
Consequences of the Proposed Action Which Cannot be Avoided . . . . .	54
4—Agencies and Persons Consulted . . . . .	56
References . . . . .	59
Appendix A: Safety and Properties of Pourvex Extra and QM-100 . . . . .	

## **List of Figures**

---

Figure 1. Location of adit in Rodgers Hollow . . . . .	3
Figure 2. Conceptual layout of UTP CAL-2 and CAL-3 tests . . . . .	5
Figure 3. Conceptual layout of UTP Large-Scale CAL . . . . .	6
Figure 4. Conceptual layout of UTP main event . . . . .	7
Figure 5. UTP schedule . . . . .	10
Figure 6. Test site location . . . . .	16
Figure 7. Rodgers Hollow stratigraphic column . . . . .	18
Figure 8. Relocation site for material removed from adit . . . . .	28
Figure 9. Overpressure vs. Range for deeply buried 75,000 lbs TNT equivalent . . . . .	31
Figure 10. Predicted peak particle velocity versus range for UPT . . . . .	33

Figure 11. Location of the New Madrid Seismic Zone . . . . .	40
Figure 12. Cumulative seismic activity on Amchitka Island, 1970-1971 . .	41
Figure 13. Seismic activity in the Central Mississippi Valley, 1974-1980 . . . . .	43
Figure 14. Approximate relationship of explosive energy yield versus magnitude . . . . .	44

## **List of Tables**

---

Table 1. UTP Test Event Explosive Weights . . . . .	2
Table 2. Alternatives Considered, Subjectively Related to the Proposed Project . . . . .	24
Table 3. Damage Thresholds from References . . . . .	35
Table 4. Composite Damage Criteria and Ranges at Which Criteria are Met for UTP 37.5-Ton Event . . . . .	35
Table 5. Motion Thresholds for Human Tolerance . . . . .	36
Table 6. Calculated Detonation Products of Canidate Explosives/1000 lbs . . . . .	47
Table 7. Calculated Detonation Products of Canidate Explosives . . . . .	48
Table 8. CB-6 Water Quality . . . . .	50

# Preface

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The Underground Technology Program Calibration Test 1 is sponsored by the Defense Nuclear Agency (DNA) and managed and conducted by the U.S. Army Engineer Waterways Experiment Station (WES). Dr. Paul Senseny is the DNA Project Officer for Underground Technology Program (UTP).

This research effort is being conducted under the direction of Dr. Jimmy P. Balsara, Chief, Geomechanics and Explosion Effects Division (GEED), and Mr. Landon K. Davis, GEED, Structures Laboratory (SL), WES. Mr. Gayle E. Albritton, Structural Mechanics Division (SMD), is the WES Program Manager for UTP.

This Environmental Assessment was prepared by Messrs. D. W. Murrell, GEED, and J. S. Shore, SMD. The assessment was reviewed by Messrs. Albritton and Davis and Dr. Balsara. Mr. Bryant Mather was Director, SL.

The essential conclusions of this effort were summarized in a Finding of no Significant Impact (FONSI), which was published as a legal notice in news media in Louisville, KY, and surrounding area. The EA itself was reviewed and approved by appropriate authority at Ft. Knox, KY, and the U.S. Army Training and Doctrine Command.

At the time of publication of this report, Director of WES was Dr. Robert Whalin. Commander was Col. Bruce K. Howard, EN.

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# Conversion Factors, Non-SI to SI Units of Measurement

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Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
miles	1609.3	metres
inches per second	2.54	centimetres per second
pounds	0.4535	kilograms
tons	907	kilograms
pounds per square inch	6896.6	pascals

# Summary

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**Introduction:** The information found in this Summary and Finding of No Significant Impact (FONSI) is based on the Environmental Assessment (EA) for the Underground Technology Program, Rodgers Hollow, Fort Knox, KY, 21 Aug 1991.

**Name of the Proposed Action:** Underground Technology Program

**Description of Proposed Action:** The U.S. Army Engineer Waterways Experiment Station proposes to conduct four conventional high explosive tests for the Underground Technology Program (UTP) at the Rodgers Hollow Area of Fort Knox, Kentucky. The purpose of the proposed action is to acquire experimental data to develop a high confidence predictive/assessment methodology for survivability of deeply buried structures.

Testing activities will involve the detonation of two, 8,000-pound (TNT equivalent) explosive charges, one 20,000-pound (TNT equivalent) explosive charge, and one 75,000-pound (TNT equivalent) explosive charge. All charges will be detonated at an approximate depth of 575 feet, and measurements of ground shock and structural response will be recorded. The explosive charge weights have been kept to a minimum consistent with test requirements. After the tests, the area will be restored to near pretest conditions.

**Anticipated Environmental Effects:** Construction activities will create temporary and minor disruptions of the local environment. Some shrubs and grasses will be destroyed, and a few animals will be displaced. Some dust and noise will be created by the construction effort. The detonations will not produce any significant airblast or ejecta. Ground shock may be perceived outside Fort Knox but will not cause any damage. Detonation products will be limited to and contained in the charge cavity and resulting fracture zone. Water quality monitoring wells will be used to ensure no unexpected migration of detonation products occurs. Due to the small quantity of hazardous detonation products and the hydrogeologic conditions of the area, no underground sources of drinking water will be affected. Air quality will not be affected by the detonations since no detonation products will be released into the air. No humans, large animals, or man-made structures will be harmed by the tests

**Conclusions:** Based on the analyses presented in the EA, no significant environmental impacts should result from the proposed action. Therefore, an Environmental Impact Statement is not required pursuant to AR 200-2, Section 6-2 and NEPA 40 CFR 1501.4e.

# **1 Introduction**

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## **Purpose and Need for the Proposed Action**

The U.S. Army Engineer Waterways Experiment Station (WES) has developed plans to implement a test program using conventional high explosives to address the issues associated with the analysis of deep underground structures. This program is called the Underground Technology Program (UTP). The Rodgers Hollow area of Ft. Knox, KY, has been selected as the test site after evaluation of geotechnical and environmental factors (see Chapter 2). The purpose of this program is to test the survivability and vulnerability of hardened underground structures to simulated nuclear attack. The results of this test program will be used to develop and verify a high confidence predictive assessment method to determine the fragility of typical underground facilities in saturated limestone.

The proposed action consists of three calibration tests and a main event. All tests will be conducted in the Louisville Limestone formation. The first calibration test is scheduled for April 1993 and is designed to consist of a single 8,000-lb (TNT equivalent) detonation, while the second calibration test will be a 8,000-lb (TNT equivalent) detonation scheduled for September 1993. The Large Scale Calibration Test will be a 20,000-lb (TNT equivalent) detonation scheduled for August, 1994. The main event will be a 75,000-lb (TNT equivalent) detonation. This test is planned for August 1995. The third calibration test and the main event will contain underground structures which will be instrumented to record their response to the explosive loads.

## **Description of the Proposed Action**

### **General**

The proposed action, referred to hereafter as UTP CAL-2, UTP-CAL-3, UTP Large-Scale Cal, and UTP Main Event will involve detonations of explosive charges at depths of approximately 575 feet beneath the ground surface. Measurements of ground shock, and structural response phenomena will be made at numerous locations.

The explosives to be used in these tests are POURVEX EXTRA or QM-100 for the main charge and Composition-4 for the boosters. Both of the candidate explosives under consideration have substantially less energy release in calories/gram than TNT, so that more of either will be required than the nominal TNT yield. Table 1 lists net explosive weights for the four tests and for each of the candidate explosives. For the remainder of this report, explosive weights will be stated in pounds of TNT equivalent, except for the Detonation Products section, where actual weights from Table 1 are used.

Table 1 UTP Test Event Explosive Weights			
Event	Explosive Weight, pounds		
	TNT equiv. <sup>1</sup>	POURVEX <sup>1</sup>	QM-100 <sup>1</sup>
CAL-2	8,000	12,035	12,810
CAL-3	8,000	12,035	12,810
Large Scale Cal	20,000	30,088	32,025
Main Event	75,000	112,831	120,094
<sup>1</sup> Based on energy release of 1020 cal/g for TNT, 678 cal/g for POURVEX EXTRA and 637 cal/g for QM-100.			

The proposed tests will be conducted deep underground. A main adit will be mined into the side of the hill which is the eastern most border of Rodgers Hollow at Ft. Knox, Kentucky (Figure 1). (An adit is defined as a nearly horizontal passage from the surface in a mine.) This adit will extend into the hill and then turn and run parallel to the ridge line. The adit will be approximately 12 feet in diameter and will have a total length of approximately 3500 feet. This main adit will slope downward at approximately 10 percent for most of its length. (A short section of upward slope will occur at the portal entrance.) This will place the termination of the adit some 350 feet lower than the entrance.

The explosive tests will be conducted in side adits off of the main adit at locations which will allow the explosives to be positioned in the proper geologic formation and will provide access for the placement of electronic gages to measure the response.

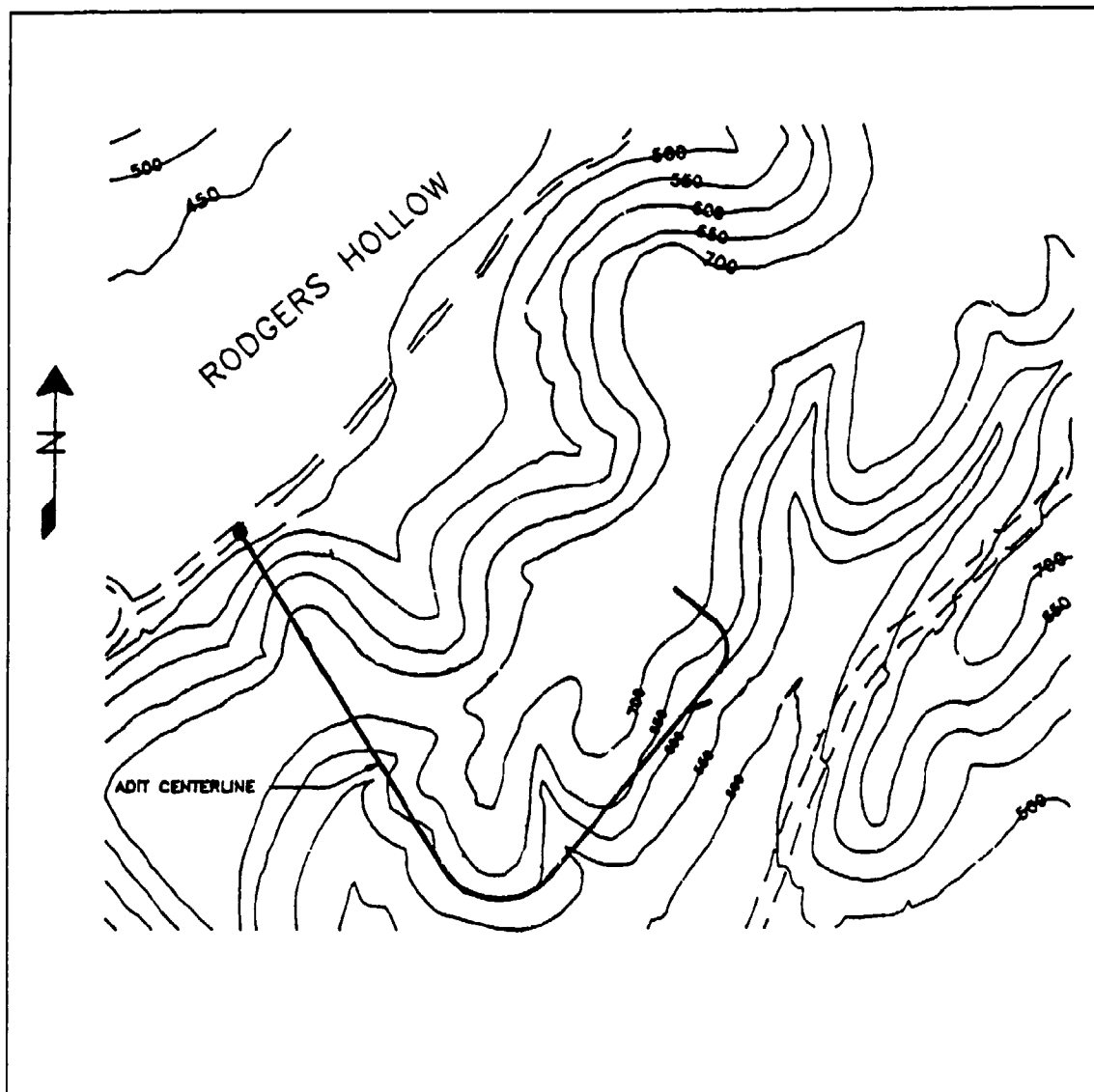


Figure 1. Location of adit in Rodgers Hollow

### UTP CAL-2 and CAL-3

The UTP CAL-2 and CAL-3 will each involve the detonation of approximately 8,000 pounds of TNT equivalent and 4 pounds of C-4. The explosive containers will be thin-walled steel spheres that will be placed at the bottom of drill holes at the end of side adits. The containers will be grouted in place, explosive will be pumped into the containers, and the adits backfilled with concrete to provide stemming. About 100 cubic yards of concrete will be required for each test.

Approximately 35 instruments to measure ground shock will be placed at various locations around the explosive charge. All gages will be placed in

horizontal 6-inch-diameter boreholes. Instrument holes will be filled with a rock-matching grout. Figure 2 shows a schematic of the conceptual layout with dimensions omitted. Dimensions and actual layout will be determined as final calculations and predictions are performed. Cables from the instruments will extend to a junction box located in the main adit and thence along the main adit to a recording van located about 150 feet away from the adit entrance. Commercial power will be utilized for all electrical needs.

### **UTP Large-Scale CAL**

UTP Large-Scale Cal will be similar in layout to the CAL-2 and CAL-3 tests in that the testbed activities will be conducted in side adits off of the main adit. This test may require one additional side adit, so that model structures and structural response gages can be properly positioned relative to the charge.

The charge weight for the UTP Large-Scale Cal will be approximately 20,000 pounds of TNT equivalent and 4 pounds of C-4. This will require a greater standoff distance from the main adit and more concrete stemming. Approximately 200 cubic yards of concrete will be required to stem the charge. The test structures will be grouted in place with rock-matching grout as will the instrument canisters and the horizontal bore holes through which the instruments will be placed. Figure 3 depicts the conceptual testbed configuration for this test.

The structures placed in this test will be scaled models of tunnel liner structures to be used in deep underground fortifications. Instruments to measure structure response as well as rock response will be positioned in and around the structure. There will be a total of 100 instrument channels recorded on this test. The cable routing will be the same as was described previously for CAL-2 and CAL-3.

### **UTP main event**

The UTP Main Event will be similar in layout to the Large-Scale Cal test, but there will be more structure and instrument locations. The structures, explosives, and instrumentation will be positioned in side adits as conceptually shown in Figure 4. There will be 400 total channels of instrumentation and 18 model structures. There will be 75,000 pounds of TNT equivalent and 40 to 8 pounds of C-4 detonated in this test to provide the proper loading intensities. As was described for previous tests, concrete will be used for stemming the charge and rock-matching grout will be used for backfill around the structures and the gages. The instrumentation cables will go from the gages to a junction box approximately 300 feet from the charge and then on to the instrument vans outside the main adit entrance.

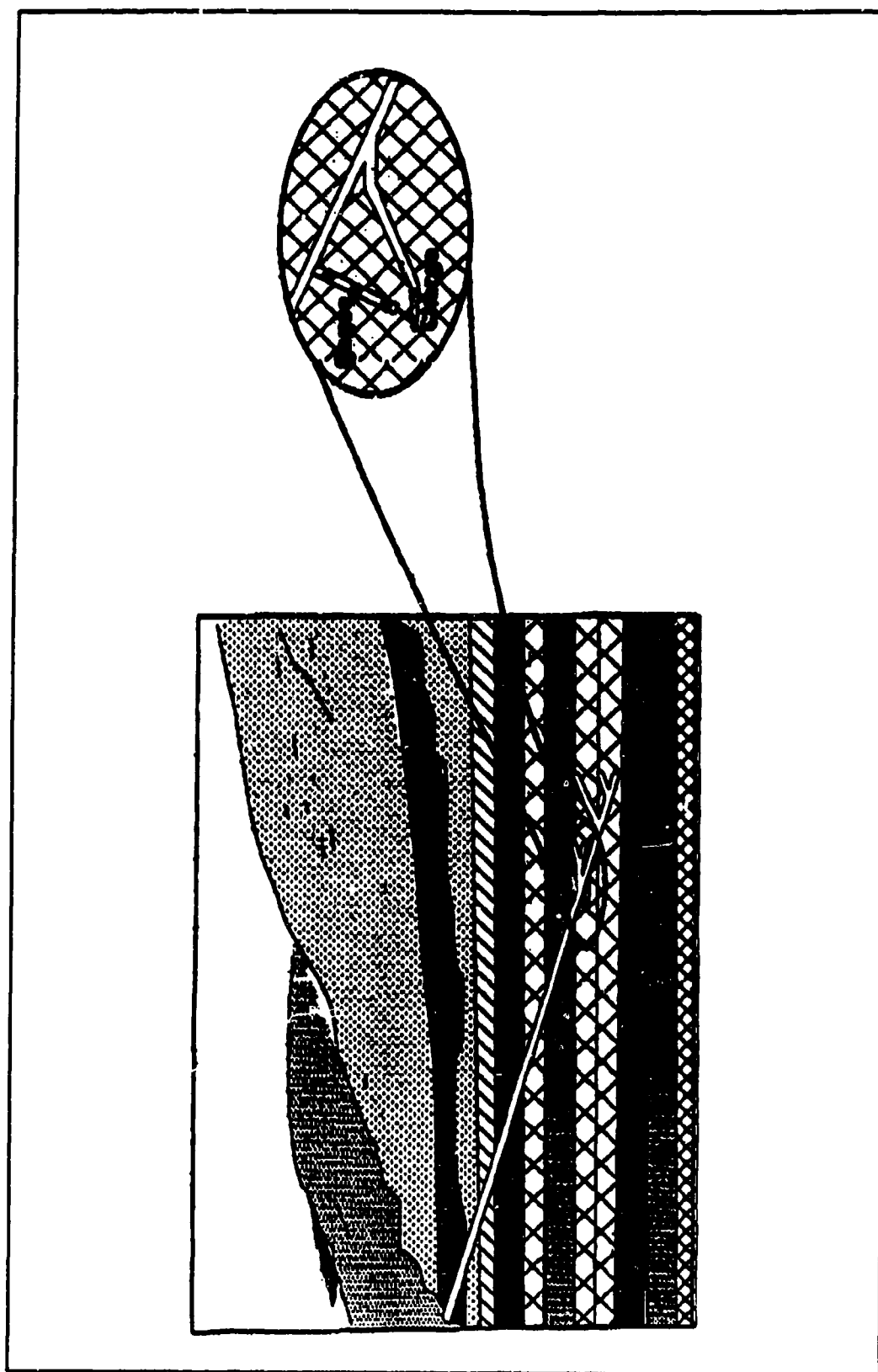


Figure 2. Conceptual layout of UTP CAL-2 and CAL-3 tests



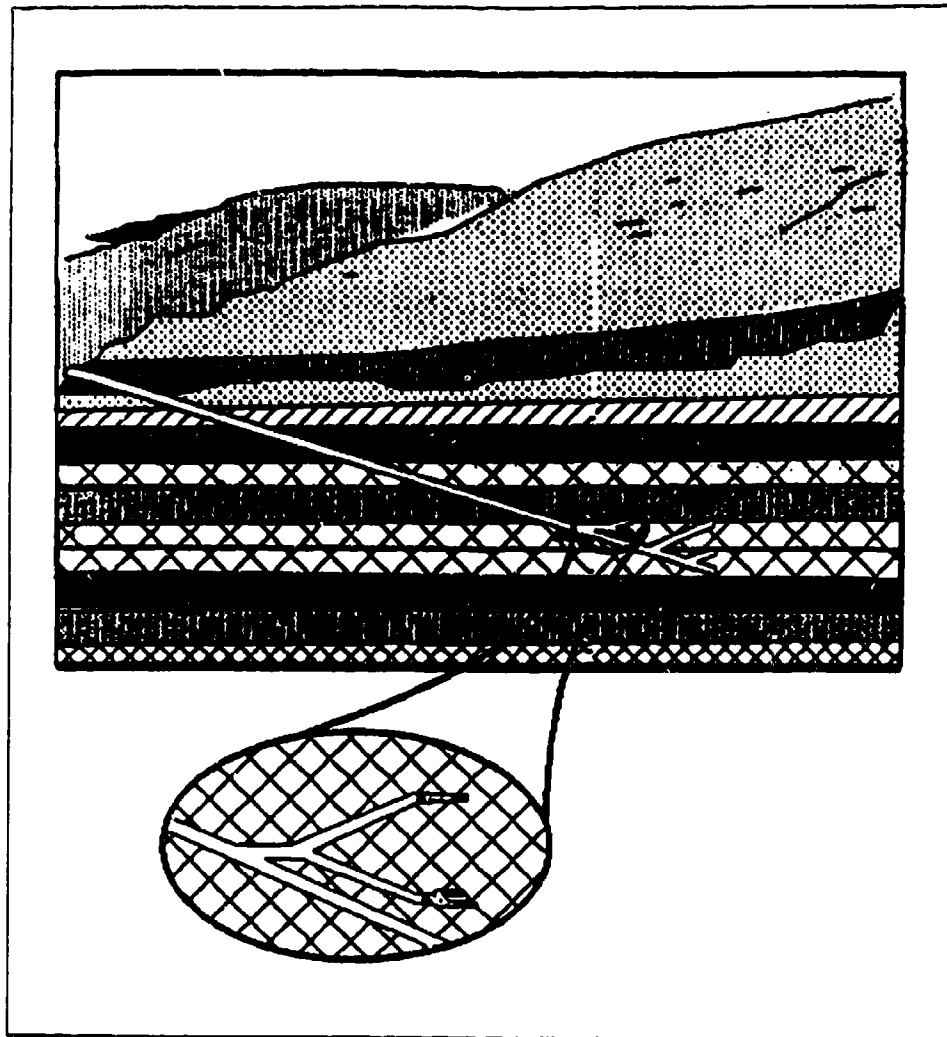


Figure 3. Conceptual layout of UTP Large-Scale CAL

After the test an effort will be made to mine back into the side adits to retrieve the testbed structures. The free field gages will remain in the testbed.

Final site cleanup and restoration will begin immediately after UTP Main Event test activities are completed.

#### Construction and testing activities

**Site operations.** Site operations in connection with UTP tests will include the following activity sequence:

- a. Clear and level the area adjacent to the entrance to the main adit.  
Dress-up the existing parking area.

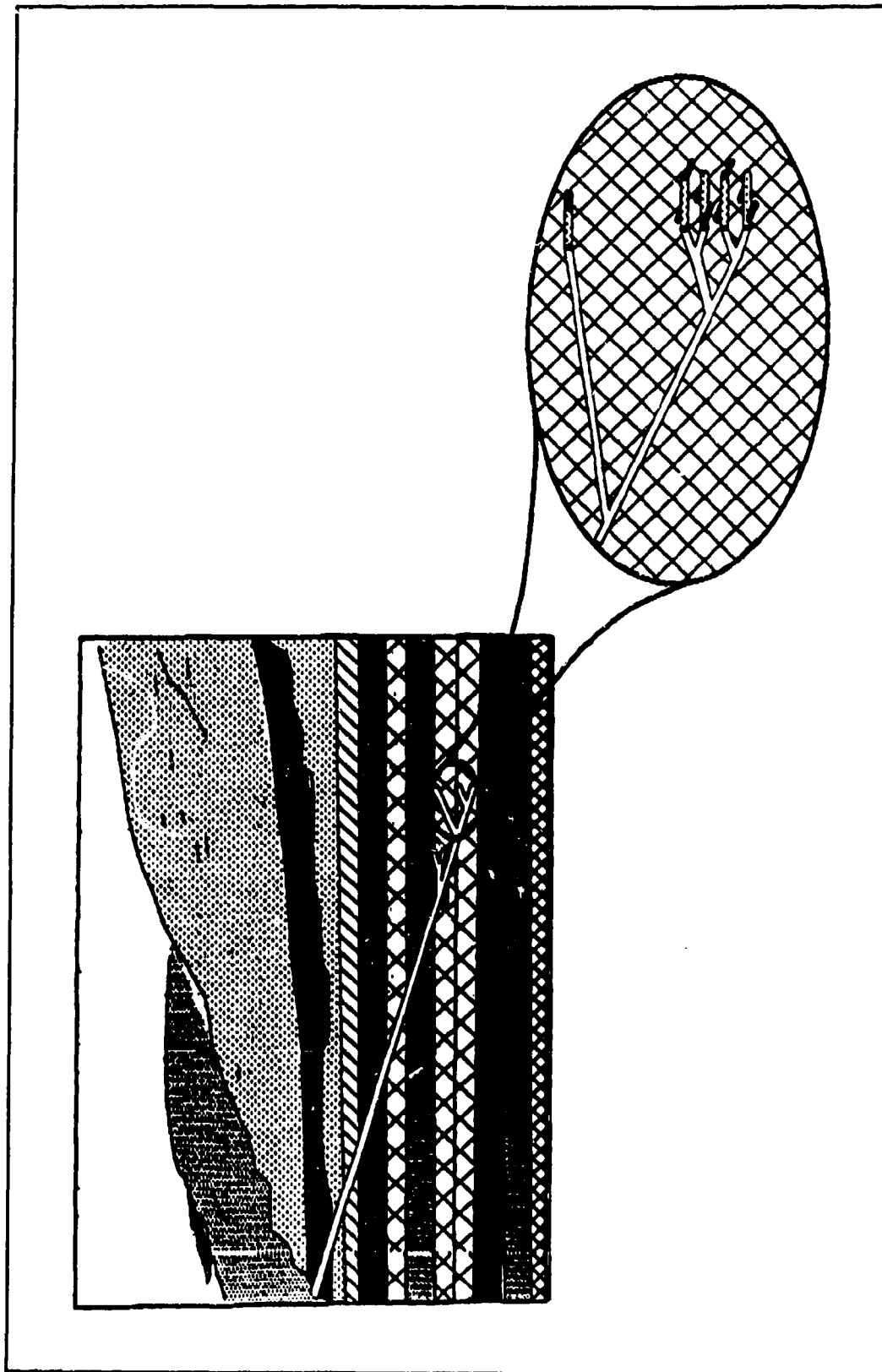


Figure 4. Conceptual layout of UTP main event

- b. Excavate and construct portal for access to adit and mine a 12-foot-diameter, 3500-foot-long adit into and along the ridge line of hill on eastern border of Rodgers Hollow. The adit will drop with a 10 percent slope to a final elevation about 350 feet below the adit entrance ground surface.**
- c. Relocate mine tailings to designated area in Rodgers Hollow and contour to be compatible with existing drainage system.**
- d. Using diesel or electric equipment, place the explosive containers and structures (for Large-Scale Cal and Main Event) for each test at the time scheduled.**
- e. Pressure check charge container and filling assembly for leaks.**
- f. Grout the container and filling assembly in place.**
- g. Repeat step e.**
- h. Drill instrument holes at various locations within the test bed for each test.**
- i. Place and grout instruments in the 6-inch-diameter holes.**
- j. Locate the instrument recording van about 150 feet from the adit entrance. Route approximately 450 cables from the van to the test bed.**
- k. Conduct system checks and fry runs as required.**
- l. Load the explosive through the filling assembly.**
- m. Place the booster/initiator assembly.**
- n. Conduct the test.**
- o. Reenter test-structure area. May involve some mining.**
- p. Recover all accessible cable.**
- q. Plug the main adit with 20-foot-thick concrete plug.**
- r. Regrade and reseed area.**

Clearing and leveling will be the minimum required to accommodate the test bed and the instrument van area. No destruction of large vegetation will be required, except perhaps at the adit entrance where a few trees may be cut to accommodate portal construction. Existing temporary roads in the immediate Rodgers Hollow area will be repaired and maintained while

preparing for and conducting this test program. The temporary roads will be accessed from Ridge Road, which is a gravel-surface road maintained by Ft. Knox authorities.

**Schedule and manpower requirements.** Approximately five years will be required to conduct these tests. Figure 5 shows the planned schedule for field operations. In summary, operations are scheduled to commence about January 1992, with the tests conducted on or about April 1993, September 1993, August 1994, and August 1995. Site restoration would be complete by within one year after completion of the final test.

A government representative will be on site during all activities, with five to ten additional personnel on site for some months immediately before each test. The mining contractor will have six to ten people on site to mine the adit. Additional persons on-site will be vendors making deliveries, and their presence will be temporary and under Corps supervision. Several official visitors from government agencies and government contractors may visit the site during the course of the program.

All project related personnel will access the site via Kentucky Highway 44 from Shepherdsville, thence via Ridge Road. Visitor control and access will be in accordance with regulations and procedures established by Range Control, Fort Knox.

**Mining Operations.** The primary construction effort required to complete the UTP is the mining of the 3500-ft main adit. This adit will be approximately 12 ft in diameter and (except for the adit entrance) will slope downward on a 10 percent grade for its entire length. A second mining operation will be required after the main adit is completed. This will entail mining several side adits and possibly a short horizontal extension of the main adit. Exact dimensions of the side adits have not been determined, but they are not likely to be more than 12 ft in diameter or more than 750 ft long. There may be a total of as many as 10 side adits, although the exact number cannot be determined at this time.

The mining will be done by a mining contractor hired by the government. This contractor will be a firm regularly engaged in this type of mining and must document good safety and environmental records and previous experience. The method of mining will be left up to the contractor, but contract specifications will state that all government and Corps of Engineers regulations pertaining to safety and environmental issues will be followed.

The most probable mining method that a contractor will use to construct this adit is drill and blast. In this method a sequence of holes is drilled in the rock and explosives are packed into the holes and detonated. The resulting rock rubble is excavated and removed. This process is continued until the desired length of tunnel is reached.

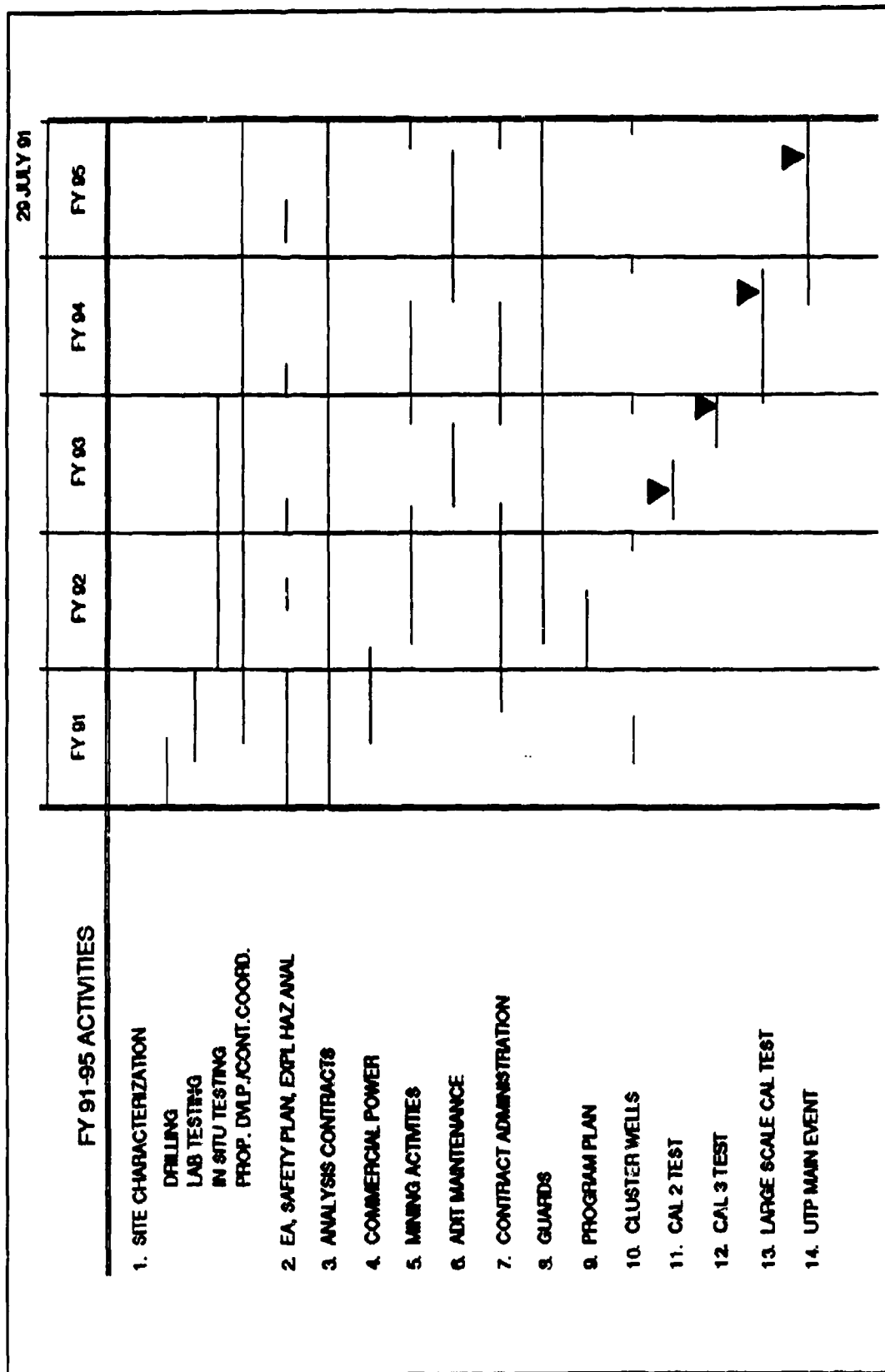


Figure 5. UTP schedule

If this method is used, water will be required to cool and lubricate the drills; and pumps will be required to remove the water from the mine. The water will be trucked to the site. The source of the water used in construction has not been determined, but the Salt River is a possible source. An analysis of the Salt River water shows that it is suitable from construction and environmental standpoints. That is, it will not damage construction equipment and will not contaminate any aquifers during construction. After the water is used it will be pumped into a series of settling tanks (probably 2) to make sure that the fines are removed. Skimmers will be used as required. If necessary, the water will be treated by a water treatment contractor so that it can be drained into the Salt River without a significant environmental impact.

The drill and blast method also requires that some explosives be on site during times of construction. These explosives will be stored in a designated explosives storage area. The contractor will be responsible for bringing the explosives to the site once each week and taking them away at the end of the week. In the event that the contractor elects to work 24 hours a day, there may be explosives stored on site around the clock.

Most of the mining operations will take place underground and in the side of a hill. The amount of explosives used at any one time will be less than 500 pounds, and the explosions will not be perceptible outside the Ft. Knox boundaries. They will be only slightly perceptible outside Rodgers Hollow. The only part of the operation that might be perceived outside the Ft. Knox boundaries is any blasting that may be required during the construction of the portal or mine entrance. In this case a detonation might be audible at the nearest house under certain atmospheric conditions, but there is no chance of damage of any kind.

The mining itself will not have any significant environmental impact. Only rock in the immediate vicinity of the adit will be disturbed. The water table will not be significantly affected. The shales are virtually impermeable, but the limestone may allow some water to seep into the mine. This seepage will be controlled by grouting and pumping. This water, as well as the construction water mentioned above, will be introduced into the Salt River under a permit granted to Ft. Knox by the Kentucky Department of Environmental Protection, Division of Water Quality. In any case, the seepage will not be enough to significantly affect the local hydrology.

Commercial sources will provide electrical power for ventilation, pumping, lighting, etc. in the mine. There will be a diesel generator for emergency power. Vehicles in the mine will be electric or diesel as required by mining safety regulations. The air in the mine will be exhausted and replaced by a ventilation system installed by the contractor as the mining progresses.

As in any construction project--especially in mining--there is great emphasis placed on safety. The mining industry has strict guidelines and the government has strict regulations that work together to help ensure a safe mine. In addition, the Corps of Engineers requires contractors to adhere to

the Corps regulations which are more stringent than those of industry or other government agencies. The Corps of Engineers will require that there be an engineer and/or a geologist trained in mine safety on site. These personnel will map the entire adit and monitor it for indications of unstable rock or other potentially hazardous conditions.

A very complete Geologic Summary Report has been compiled (Reference 1) which has characterized the rock over the length of the adit. By knowing the type and condition of rock that will be encountered, safety has been built into the adit design.

**Test bed instrumentation procedures.** For each test the gage placement procedures will be the same. For CAL-2 and CAL-3 approximately 35 active instrumentation gages located within 60 feet of the charge will be used to measure ground shock from this test. These will be free-field measurements which include measurements of soil stress and ground motion. For the Large-Scale Cal there will be approximately 100 instrumentation gages, and for the Main Event there will be approximately 400. For the Large-Scale Cal and the Main Event, however, some of the gages will be used to record structural response.

All free-field gages and canisters will be placed in 6-inch-diameter boreholes. The boreholes will be drilled either by standard rotary methods using drilling mud for circulation or some other drilling method. Upon completion of the emplacement of a gage, the gage hole will be backfilled with rock-matching grout. The constituents of the grout mix will be a combination of some or all of the following: Barite, portland cement, bentonite clay, sand, and water. The grout will be pumped into the hole, where the grout will be allowed to set for a short time while the canister or gage position is maintained.

The cables from the gages or canisters will be routed out the horizontal boreholes and joined at a common junction box and jointly routed to the instrumentation recording van via the main adit.

**Explosives and Explosives Safety.** The procedures for installing the explosives will be in accordance with DOD explosive safety regulations and will be monitored by designated WES explosives blasters. The site will be manned 24 hours/day. During nonduty hours, the site will be patrolled by a contract security guard. Storage of any explosives on-site will be in accordance with DOD regulations and will utilize portable storage containers and existing fenced explosive storage areas.

The following is a description of the explosive types to be used in the proposed test program.

- a. *POURVEX EXTRA or QM-100.* POURVEX EXTRA and QM-100 are commercially available blasting agents commonly used in mining and quarrying operations. They are both non-cap sensitive, and a high

explosive booster must be used to detonate. They are considered "oxygen balanced" explosives that were specifically developed for use under water or other heavily confined applications. Because they are oxygen balanced, complete oxidation occurs in the fireball, and EPA specifically prohibited substances are not produced (Chapter 3). POURVEX EXTRA and QM-100 are pumpable and are available in bulk formulations. POURVEX EXTRA is manufactured by Explosives Technologies International (formerly DuPont's explosive manufacturing capability). QM-100 is manufactured by Ireco Chemical Company. Appendix A contains additional information on POURVEX EXTRA and QM-100 that has been provided by the manufacturers.

- b. *C-4 explosive*: Standard, military-grade Composition-4 explosive will be used in the charge booster assembly. Approximately 4 to 8 pounds of C-4 will be used in each of the UTP tests.
- c. *Exploding Bridge Wire Detonators (EBW)*: A high-voltage, extremely safe detonator will be used to initiate the explosive reaction. The EBW to be used contains 78 mg of PETN, and 994 mg of C-4 as initiating explosive.

In the undetonated state these explosives are environmentally benign. If a spill occurs or if a test is canceled after the explosives have been loaded, the explosives will be recovered and none will be left in the environment. These explosives are stable in water and will not dissolve. QM-100 and POURVEX EXTRA are not considered hazardous to the environment.

**Dry Run and Detonation.** Following the emplacement of the gages for each test, as much time as necessary will be devoted to a complete system checkout and "dry run". The same procedures will be followed as if it were the actual detonation, except for the final explosive placement and arming. Gage recording will be monitored to determine any system malfunctions. When the results of the dry run are determined to be satisfactory, test readiness will be announced to the Ft. Knox Range Control.

On the morning of the test day, the area will be secured and the explosive loading will begin. The charge container will be certified to be free of water, and the explosive pumped into the container. The initiation/booster system will then be placed in the center of the charge. A countdown system will be employed which will allow the project manager positive control to abort the detonation up until the firing signal is actually initiated. During the countdown, the project manager will be in constant radio contact with Fort Knox range officers in the event that Fort Knox should need to abort the detonation for any reason. A Safety Plan and Explosive Hazard Analysis will be prepared and approved by Ft. Knox and DNA prior to any explosive testing.

Meteorological conditions should not be a factor, short of intense thunderstorms at shot time. All explosive operations will be placed on hold whenever a lightning hazard exists. Airspace clearance will not be required.



**Construction of support facilities.** No permanent support facilities will be constructed at the proposed test site. An electrical power substation will be installed, but will be removed at the end of the project if Ft. Knox officials so request. Two trailer vans will be used to house the instrumentation recording equipment, and two trailer vans will provide administrative support and storage. Existing temporary sheds will be used to store tools and equipment for use during preparation of the test and for posttest recovery. Temporary fencing, cable, or rope may be used to secure areas of limited access.

Commercially available electrical power will be used at the test site. Lights will be operated at night to aid security surveillance.

Water used in construction will be brought to the site by truck. Potable water for construction personnel will be carried to the site by designated personnel in large coolers designed for that function.

Sanitation will be provided by the use of portable, self-contained latrines serviced by a local waste management contractor. Nontoxic, nonhazardous, solid waste garbage will be hauled to a local dump. No toxic or hazardous solid waste will be generated during construction. For discussion of explosive detonation products, Chapter 3, Charge Cavity and Fracture Zone.

**Site cleanup and restoration.** During the mining operation the limestone and shale removed from the adit will be spread over the area designated by Soil Conservation Service or Ft. Knox Directorate of Engineering and Housing personnel for that purpose (Chapter 3). The depth covered will vary depending on the contours specified. Topsoil removed and stockpiled prior to the placement of the tailings will be replaced to approximately the original depths. The area will be immediately reseeded and allowed to revegetate with native grasses as per Ft. Knox Wildlife Service instructions. All material associated with these tests will be removed from the surface of Rodgers Hollow. All material not requiring additional mining will be removed from below the surface.

**Use of facilities and resources of the area.** WES personnel will be housed in motels and apartments in the Louisville/Shepherdsville area, and will eat in local restaurants. Local businesses will be utilized for incidental supplies and maintenance. Local contractors will be utilized for equipment rental required in construction and site cleanup, and for sanitation and guard service.

# The Test Site Environment

## General

The proposed action is to be sited in the Rodgers Hollow area of the Fort Knox Range. Rodgers Hollow is approximately 7.4 miles west-southwest of Shepherdsville, Kentucky, in Bullitt County. Numerous previous tests have been conducted by WES in Rodgers Hollow since 1980.

## Location of the proposed test site

The proposed test site is located within the boundaries of the Fort Knox Military Reservation (FKMR). It is in the northeast range area known as the Rodgers Hollow Artillery Area, in Training Area 17. Geographic coordinates of the proposed test site are approximately 37° 57' 20" N and 85° 50' 01" W. The elevation in Rodgers Hollow is approximately 490 feet above MSL. The site location is shown in Figure 6.

FKMR presently covers an area of 109,362 acres and is located approximately 30 miles south of Louisville, Kentucky, in an area characterized by rolling hills and wooded areas. It is bounded on the north by the Ohio River, cultivated lowlands, wooded areas, and hills; on the east and south by farm land, hills and wooded areas; and on the west by farm land, Otter Creek Park, and the Ohio River. The cantonment area consists of approximately 6,000 acres and is located in the west central part of the Reservation. The town of West Point is located just north of the northern boundary. The town of Radcliff is adjacent to the southern boundary; Vine Grove is a short distance south, and the town of Muldraugh is surrounded by the Reservation. Parts of Hardin, Meade, and Bullitt Counties are located within the boundaries of the Reservation. Portions of the information presented in the Test Site Environment section of this report were obtained from the latest available environmental report (*Analytical/Environmental Assessment Report 1987*).

## Physiography, Geology, and Hydrogeology

The Rodgers Hollow area is characterized by a relatively flat valley floor surrounded on three sides by hills. The area is drained by a small unnamed creek that branches into two forks in the northern portion of the hollow. This creek flows into the Salt River approximately 0.6 miles southwest of the entrance of Rodgers Hollow.

The overburden material in Rodgers Hollow consists of quaternary alluvium and lacustrine deposits; generally light-tan to dark-brown silts and clays with varying amounts of sand, gravel, and rock fragments. It is not uncommon for zones of gray to olive-gray silty clay to be intermixed with the brownish material. There is a water table in the overburden, which slopes toward the drainageways in the hollow and nominally parallels the ground

# Fort Knox, KY

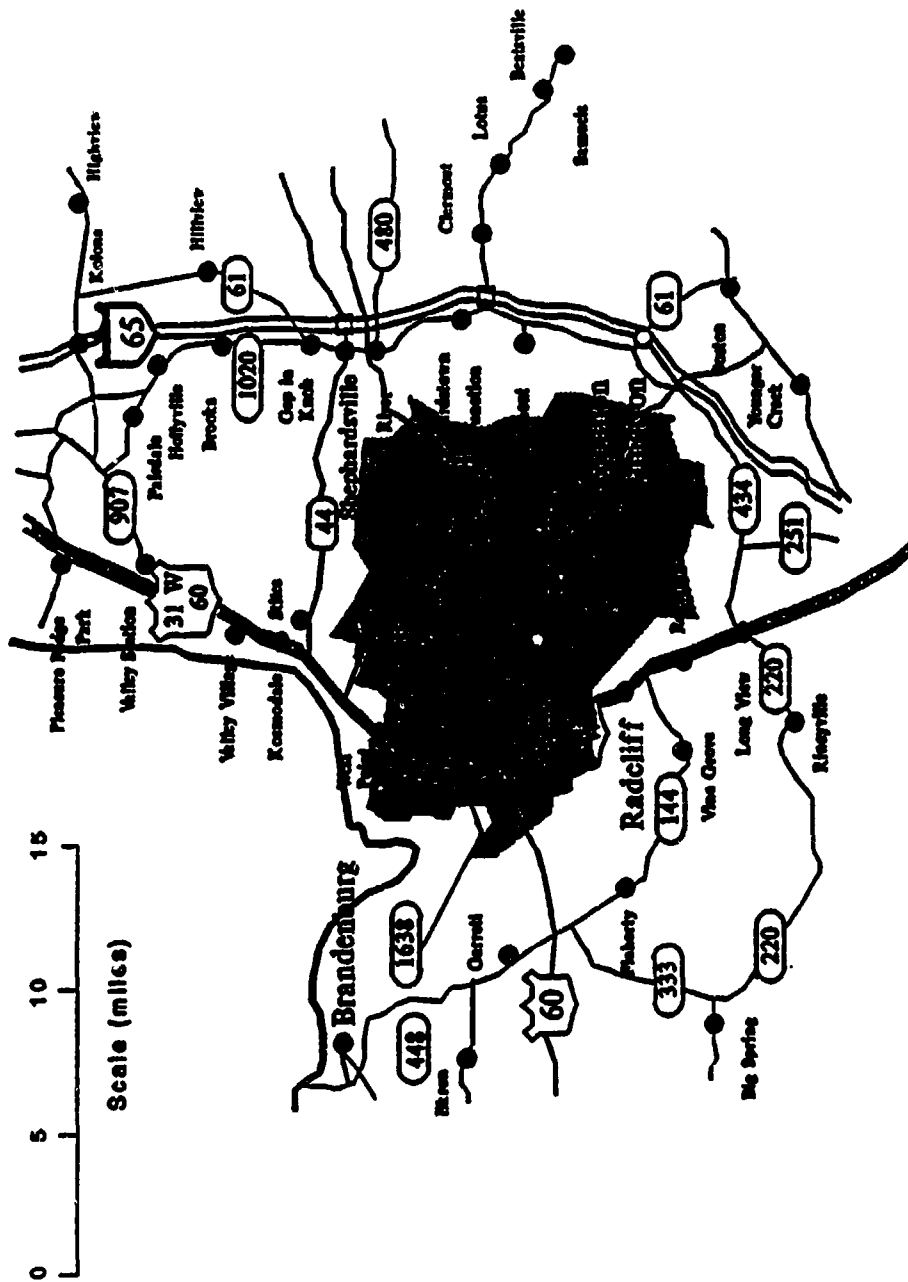


Figure 6. Test site location

surface contours. In many areas of Rodgers Hollow, the water table is 20 to 6 feet below the ground surface. The bedrock in the hollow is the New Providence shale, a gray silty shale of Mississippian age. It belongs to the Nancy member of the Borden formation which was deposited approximately 350 million years ago. Depth of the rock is variable but is generally shallower near the surrounding ridges and deeper towards the mouth and in the central portions of the hollow. The depth of rock varies depending upon location within the hollow (Zelasko 1986). Water injection tests have shown the New Providence shale to be of very low permeability; water influx to boreholes occurs through gravelly lenses in the soil overburden.

The New Providence shale extends to a depth of approximately 180 feet where an 80-foot-thick layer of older New Albany shale of Devonian age (400 million years old) occurs. Exploratory drilling indicates that this is underlain by the Louisville Limestone. The Louisville Limestone is approximately 110 ft thick and is underlain by the Waldron Shale which is approximately 10 ft thick. The Laurel Dolomite formation lies below the Waldron Shale and this is underlain by the Brassfield Limestone. A typical stratigraphic column of the area is shown in Figure 7. A complete description of the Rodgers Hollow geology is given in (Lachel 1991).

### **Climate**

The climate is moderate with warm humid summers and mild winters. Below-zero temperatures occur occasionally but seldom last longer than a few days. The maximum temperature occasionally reaches above 100 F. The mean annual rainfall is 45 to 55 inches and is generally well distributed throughout the year. Driest weather often occurs during the late summer months of September and October. The average frost-free period occurs from 20 April to 15 October. The growing season is 183 days. Winds are moderate, averaging around 9 knots per hour on a yearly basis with prevailing wind directions from the southwest and northwest. Adverse weather occurs from occasional tornadoes and localized hail storms.

### **Air quality**

In the report, "Designation of Air Quality Maintenance Areas for the State of Kentucky," published by the Commonwealth of Kentucky, Fort Knox is not included as a Standard Metropolitan Statistical Area (SMSA) or an Air Quality Maintenance Area (AQMA). All data presented indicate that Fort Knox does not exceed Federal or State standards and will not be designated as an AQMA. Fort Knox has identified and inventoried all known sources of air pollution in an EPA Air Pollutant Emissions Report. The area of influence of Fort Knox lies in the North Central Quality Control Region (NCQCR).

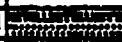

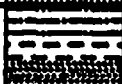











SYSTEM	SERIES	GLACIATION	FORMATION, MEMBER, AND BED	LITHOLOGY	THICKNESS (FT)
QUATERNARY	HOLOCENE		YOUNGER ALLUVIUM		0-20
	PLEISTOCENE	ILLINOISIAN	LACUSTRINE, LOESS & OLDER ALLUVIUM		0-85
TERTIARY ? & QUATERNARY	PLIOCENE ? & PLEISTOCENE		TERRACE DEPOSITS		0-90
MISSISSIPPIAN	MERAMECIAN		ST. LOUIS LIMESTONE		
			SALEM LIMESTONE		ONLY LOWER PART PRESENT
			HARRISBURG LIMESTONE		40
	OSAGIAN		BORDEN FORMATION MULDRAUGH MEMBER		60-70
			NANCY MEMBER		180
			NEW PROVIDENCE SHALE MEMBER		180
	KINDERHOOKIAN				
DEVONIAN	MIDDLE & UPPER DEVONIAN		NEW ALBANY SHALE		78
			JEFFERSONVILLE		7-9
SILURIAN	NIAGARAN		LOUISVILLE		102
			WALDRON		8-10
			LAUREL		45

Figure 7. Rodgers Hollow stratigraphic column

## **Ambient noise level**

Noise sources associated with installation activities which contribute to the general ambient noise levels include: rotary and fixed wing aircraft, weapon firing, and operation of civilian and military vehicles. Other sources of noise have been identified by the Preventive Medicine Activity (MEDDAC). Reports are contained in their files. The U.S. Army Environmental Hygiene Agency (USAEHA) has conducted noise surveys and developed noise contours for noises emitting from the installation. These surveys are on file at the Environmental Management Division, Directorate of Engineering and Housing, Fort Knox. The reports contain the results of a computer simulation of the blast noise environment generated by tank guns, artillery pieces, and demolition activities at Fort Knox. The noise levels produced by Fort Knox activities are essentially the same as have been produced for the past 15 to 20 years.

## **Ecology**

**General.** The ecology of Rodgers Hollow is typical of that found in other adjacent areas at Fort Knox. The Fort Knox Environmental Study has identified no endangered species of flora or fauna inhabiting Rodgers Hollow. However, the Cedar Point Branch area, approximately 1.7 miles from the proposed test site, is a possible habitat of the Indiana Bat and the Eastern Gray Tree Frog. The Cedar Point Branch area also contains a member of the mint family, *Synandra*, that is designated as a candidate for federal listing.

**Vegetation.** The native tree cover in the Fort Knox area consists of the Oak-Hickory type which comprises approximately 60 percent of the dominant and co-dominant tree cover. This group of trees is found almost entirely on ridge tops and southern slopes. Other species of trees growing in the area consist of mixed hardwoods found primarily in coves and on northern slopes. This group of trees includes ash, beech, black locust, cherry, elm, hickory, maple, oak, walnut, and yellow poplar. In the bottomlands along the creeks and rivers, the predominant species includes black gum, cottonwood, elm, hickories, oaks, live birch, soft maples, sweet gum, sycamore, and willow.

The vegetation varies widely outside of the cantonment area. On the level to rolling land, there exists many species of small shrubs, and undergrowth of weeds, vines, and briars with a cover of Korean Lespedeza and sweet clover where the land has not been disturbed recently. Several acres of Kentucky Bluegrass exist on the northern portion of the reservation in the bottomland near West Point, Kentucky.

On the more intensively used areas in and around the cantonment area, there is Kentucky Bluegrass, Chewings Fescue, Redtop, Kentucky 31 Fescue, Sweet Clover, and White Dutch Clover. Landscape plantings around the family quarters are characterized by slow growth, compactness, and low maintenance qualities.

Fort Knox woodlands actually total about 61,000 acres and have been under a woodland management plan since 1954. They are managed under a multiple use, sustained yield, management program. Multiple use includes primarily military land use, timber, and wildlife management. Forest fire protection is a major function. Management is generally for hardwoods, with pines being planted on the poorer sites.

**Wildlife.** Prior to the acquisition of land areas which comprise Fort Knox, deer, grouse, and wild turkey were once indigenous to the area. These species had become extinct because of intensive farming which eliminated favorable habitat conditions. In 1942, the bulk of the acreage which is now Fort Knox was acquired, and natural reproduction and succession of plants through various stages was left to nature. In 1955, thirty-five white-tail deer were reintroduced on the post. In 1966, there were many indications, confirmed by wildlife biologists, that there was an overpopulation of deer, approximately 15,000. The harvest season was extended, and general public hunters by the thousands have participated in the annual deer hunt. Thus, the winter herd has been reduced to 4,000 to 5,000 which is in keeping with the available winter food supply. Wild turkey and ruffed grouse were stocked in 1965 to 1966. These wildlife species have been protected by enforcing a closed hunting season. The turkey has reproduced, and several hundred are now on the reservation. In the spring of 1973, a spring gobbler hunt was conducted for the first time. Other principal species of wildlife found on the post and their estimated population are:

Bobwhite Quail	10,000 - 12,000
Gray & Fox Squirrel	50,000 - 60,000
Cottontail Rabbit	10,000 - 12,000
Mourning Dove	9,000 - 11,000
Raccoon	1,500 - 2,000
Woodcock	(Migratory)

Some of the non-game birds are: hawks, woodcocks, snipes, killdeers, pigeons, owls, whippoorwills, swifts, larks, hummingbirds, flickers, woodpeckers, fly catchers, starlings, sparrows, blackbirds, finches, goldfinches, coots, sapsuckers, swallows, martins, blue jays, ravens, crows, chickadees, wrens, mockingbirds, catbirds, thrashers, robins, thrushers, bluebirds, warblers, meadowlarks, orioles, cardinals, vultures, and kingfishers.

Nonmanaged piscine species found in lakes, streams, and rivers include: alligator gar, shad, bullhead catfish, small-mouth bass, green sunfish, rock bass, fresh water sculpins, hog suckers, carp, golden shiners, buffalo, flathead catfish, white perch, long ear sunfish, pumpkinseeds, crappie, white suckers, northern red horse, cheek chubs, and dace.

## **Archaeological, historical, and cultural resources**

The first systematic investigation of cultural resources at Fort Knox was conducted in 1978 and 1979 by the University of Kentucky. The stage I survey sampled 25 percent of 96 hunting areas, identifying 381 sites. The resulting inventory/management document provides background information for assessing damage and losses of the cultural resources to be impacted by the proposed action.

Approximately 20 percent of Training Area 17 has been surveyed; 10 sites have been identified. Two of the sites are designated as part of Research Management Unit 9, potential National Register quality, deserving further work for verification. The remaining sites were not considered to warrant further management attention based on land use patterns at the time of the initial survey. No sites have been identified in the proposed test site area (*Analytical/Environmental Assessment Report* 1987).

## **Other related federal activities**

The Rodgers Hollow test site area has been used since 1980 for high-explosive testing. An average of more than one test per year has been conducted there. Existing at the test site are the following:

- a. Sixteen restored test beds, currently revegetating.
- b. One 4,500 by 20 foot cleared area for cables, currently revegetating.
- c. Two explosive storage areas (approximately 50 by 50 feet), fenced.
- d. One graveled trailer park area (approximately 250 by 100 feet).
- e. One old trailer park area (approximately 200 by 100 feet).

The above activities were conducted over the last 10 years in accordance with the Environmental Impact Assessments prepared for the Silo Test Program, May 1980 (Zelasko 1986); The Silo Test Program 4.5b, May 1987 (*Environmental Impact Assessment Report* 1987); The Cofferdam Concept Test Program, September 1987 (*Environmental Impact Assessment Report* 1987); The Underground Technology Program Calibration Test 1, October 1990 (*Environmental Impact Assessment Report and FONSI* 1990); and several categorical exclusions.



## **2 Alternatives to the Proposed Action**

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### **General**

The objectives of the proposed action have been reviewed with respect to national defense requirements, and have been judged important and of high priority. The proposed test will use high explosives to generate ground shock in a method that is least disruptive to the environment, yet meets the requirements/objectives of the test program.

During the test planning process, a number of reasonable alternatives were considered, including changes in the explosive weights and scale, in order to reduce environmental impact. The criteria used to help evaluate the acceptability of a particular alternative and to assist in balancing the potential environmental harm against national defense included:

- a.* Maximize the attainment of required national defense objectives.
- b.* Minimize the socioeconomic consequences.
- c.* Minimize the environmental consequences.
- d.* Minimize the test cost.

The social variables considered were physical damage to man's structures, activities, or heritages, loss of recreational facilities, and/or aesthetic qualities. The major environmental variables evaluated were (1) permanent changes in the physical environment which would affect human health or welfare, and (2) direct or indirect effects on animals, plants, or ecosystems, especially changes which would temporarily or permanently alter the land characteristics. Economic variables related to the actual cost of the proposed test program include the direct costs of logistics, construction test support, and data analysis.

## **Evaluation of Alternatives**

The following alternatives to the proposed action as summarized in Table 2 were analyzed but are not recommended.

### **No action**

The proposed action is vitally needed by defense agencies concerned with nuclear weapons deployment as they pertain to the survivability/vulnerability of deeply buried structures in rock media. Not conducting the tests would leave serious and detrimental voids in the strategic data base which limits the ability of planners to provide comprehensive defense goals. No environmental impact would occur if no action is taken.

### **Conduct test at other locations**

The UTP has, as an integral part of its requirements, a very specific set of geological criteria. For the past three years, an extensive and costly site selection effort has been pursued. During this process, many prospective sites throughout the central and western United States were investigated. These included sites on private land as well as DOD or other Government land. The selected test site at the Rodgers Hollow location is the only area which meets the required geotechnical criteria, whose current land use is consistent with the proposed action, and which will minimize possible environmental disruptions.

### **Reanalysis of existing data**

These tests are required for the validation of empirical predictions and theoretical calculations upon which strategic decisions will be based. No high-level stress or motion data exists for this or similar geologies. Extrapolation of data from greatly different geologies and/or much lower stress levels would not be a technically valid approach. No environmental impact would occur as a result of reanalyzing existing data.

### **Reduce the scope of the project**

The explosive size has already been scaled down to the minimum required to meet the project requirements. Further reductions in simulator size would not provide a reliable answer to the question posed. Reducing the scope of the project would reduce the environmental impact.

Table 2 Alternatives Considered, Subjectively Related to the Proposed Project					
Alternative	Test Objective	Social Disruption	Ecological Disruption	Cost	Overall Evaluation
No action	Cannot be met	Less (none)	Less (none)	Less (none)	Unacceptable due to national defense need.
Reanalysis of existing data	Cannot be met	Less	Less (none)	Unknown-probably less	Unacceptable. No data exists in the required geology at high stress levels.
Conduct tests at other location	Cannot be fully met	Similar (Site Dependent)	Similar (Site Dependent)	Greater	No other site currently meets test objectives.
Reduce scope and/or size	Cannot be fully met	Possibly less	Possibly less	Probably less	Size of tests now a minimum to meet program objectives.
Simulate in a laboratory	Cannot be met	None	None	Unknown	Unacceptable. Lack of confidence in exaggerated scaling or non-representative geology.

### **Simulate in a laboratory**

The explosive size is at a minimum to meet the program requirements and far too large for laboratory testing. No other simulation techniques will meet the program objectives. No environmental impact would occur as a result of simulating the tests in a laboratory.

### **3 Environmental Consequences of the Proposed Action**

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#### **Environmental Consequences of the Proposed Construction**

##### **General**

On the surface the proposed test site will occupy a rectangular area approximately 2,500 by 500 feet within Rodgers Hollow adjoining Range Area B in Bullitt County, Kentucky, and within the boundaries of the Fort Knox Military Reservation. Within the proposed test site area, approximately 80,000 square feet (2 acres) of land at the proposed site will be cleared of vegetation. The clearing will be kept to an absolute minimum necessary for construction and placement of the mine tailings. The topsoil will be removed as needed and stockpiled to be placed over the mine tailings.

Settling tanks will be used to prevent particulate material that may be in any water coming from the mine from reaching the creek in Rodgers Hollow. If analysis of the water indicates that further treatment is needed, it will be done by a water treatment contractor. The quantity of water coming from the mine is expected to be small. If necessary the water can be piped to the Salt River to lessen the impact on the creek in Rodgers Hollow.

Approximately 5,000 linear feet of 6-inch diameter holes will be drilled for instrumentation purposes. Both the adits and the instrument holes will be backfilled with a grout which matches the mechanical properties of the in situ material. This grout will contain Portland cement and naturally occurring soil materials (bentonite clay, sand, etc.).

A previously established gravel road will be used for site access, with some minor improvement due to washouts subsequent to its last usage. Isolated instances of brush clearing for survey operations may be necessary.

The area proposed for use on this program which is outside the adit lies within areas used for previous tests. Disturbance of vegetation and topography will be kept to a minimum, and will be less than has occurred on previous large tests.

### **Air quality**

There will be minor localized increases in airborne dust due to the movement of vehicles transporting equipment and personnel from the hard surface highway to the test area by gravel and dirt roads, grading and leveling the proposed test bed, moving earth in the construction of the test bed, drilling, and trenching for instrumentation cable burial. Natural rainfall will result in some dust suppression. It is expected that the construction activities will be very localized, and the resulting dust will be insignificant when compared to natural dust phenomena. Because most construction activities will take place in the underground adit, there will be less dust than has occurred on previous large tests.

Vehicles and equipment which will be involved in the test operation will produce minor amounts of gaseous emissions, but the small number of vehicles and equipment in use at any one time is expected to cause trivial changes in air quality.

### **Noise impact**

The impact of noise is a function of the presence of people who might be affected. Because of the semi-remoteness of the test area, it is not expected that the noise impact will be significant.

Noise will result from vehicle and equipment usage. Because of the limited amount of vehicle or equipment usage and because all vehicles and equipment have exhaust mufflers, it is expected that noise impact will be minimal.

### **Geology and Soils**

During the construction of the adit a total of approximately 29,000 cubic yards of rock will be mined from the adit and relocated to a designated area in Rodgers Hollow. This 29,000 cubic yards will consist of about 8,000 cubic yards of New Providence Shale, 5,000 cubic yards of New Albany Shale, and 16,000 cubic yards of Louisville Limestone. The relocation area is that portion of Rodgers Hollow near the proposed portal site and just off the roadway on the creek side (Figure 8). The material will be contoured to match the existing drainage patterns, covered with topsoil, and reseeded to reduce erosion. Temporary rerouting of some drainage may be required to reduce erosion during construction.

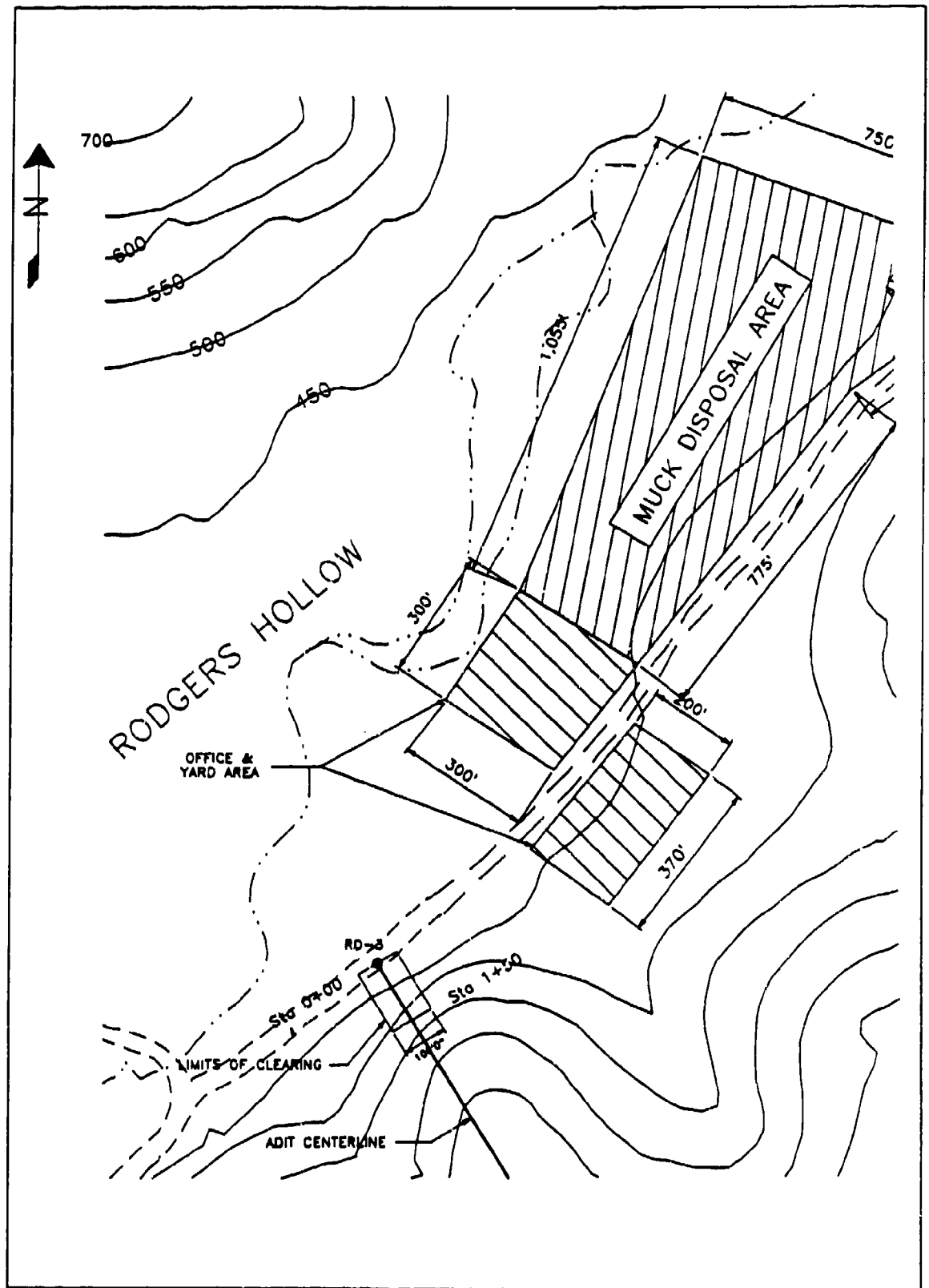


Figure 8. Relocation site for material removed from adit

The material to be relocated will be composed of rock rubble with diameters ranging from a maximum of approximately 24 inches to a minimum of near zero inches. The fines created during the mining process will be trapped in settling tanks, covered with top soil, and then reseeded. Some of the limestone may be used by Ft. Knox to improve the roads in the area. There are no acidic rocks involved and the organic material in the oil shale is very stable and will not leach out. This organic substance is known as "kerogen" and is only active at temperatures above 600°F. There are thousands of acres of this shale naturally outcropping and causing no environmental problems. In addition, the New Albany Shale that has been exposed at highway cuts offers further evidence that this material will not have an environmental impact.

Some transportation of fines into the Rodgers Hollow creek will be unavoidable, but the quantity should be less than that from previous large field tests in the hollow because the amount of surface disturbance will be much less.

There will be no significant environmental impact to or by the geology or soils in the construction phase of the program.

#### **Ground water quality**

No significant degradation of ground water quality will occur as a result of the proposed construction. If groundwater is encountered during construction, the groundwater will be isolated from the mine by a tunnel liner sealed with grout.

#### **Hazardous materials**

No hazardous wastes will be produced by this construction effort. After the test, excess explosives will be disposed of in accordance with Local, State, and Federal Regulations, i.e., unused POURVEX EXTRA or QM-100 will be returned to WES or detonated in small quantities for training purposes. The fuels will be returned to the fuel supplier. This construction will not limit future land use in Rodgers Hollow.

Fuels will be stored in above ground tanks and precautions will be taken to avoid spills. The fuel storage yard will be constructed in such a way that if an accidental spill should occur, the fuel would be confined and clean-up procedures could take place quickly with minimal environmental effects.

The blasting agents that will be used will pose little environmental threat if an accidental spill should occur (see Appendix A). The explosives are nearly insoluble in water, and since they are very stable and nonsensitive, cleanup can be accomplished safely and quickly.



# Environmental Consequences of Explosion Phenomena

## General

The explosive phenomena (e.g., airblast, noise, ground shock, cratering and ejecta, dust, and explosive detonation products) are evaluated in this section for the proposed detonation.

Human health and safety will not be compromised in any way. The airblast and noise effects will be essentially nil since the tests will have an overburden of approximately 575 feet of earth. The ground shock will be of sufficient magnitude to be perceptible outside the Fort Knox range area, but will not be of sufficient magnitude to cause damage. No detonation products will be released to the atmosphere. The dust cloud created by the explosion will be negligible to nonexistent, and will quickly dissipate and settle. Dust will cause no threat to human health and safety.

The phenomena of large yield high-explosive detonations has been discussed in great detail in previous environmental assessments of large HE test events. In addition to those mentioned previously for tests at Fort Knox (References 4, 5, and 6), these include: HARDPAN I (Gould 1974), PreDICE THROW (*Environmental Impact Assessment* 1975), DICE THROW (*Environmental Impact Assessment* 1976), HAVE HOST (Ristvet 1979), MISERS BLUFF Phase II (Gould and Harner 1977), DISTANT RUNNER (Gould 1980), MILL RACE (Gould and Rowland 1980), DRY CARES (Ristvet 1982), and Deep Underground Program (Ristvet 1987). The following summary of the explosion phenomena utilizes the above references.

## Airblast and Noise

**Airblast and Noise predictions.** Due to the deeply buried configuration of this experiment (scaled depth,  $R/w^{1/3}$ , of approximately 13 and greater), the airblast and noise produced will be insignificant and probably not audible much outside the confines of Ft. Knox. Calculations based on similarly configured tests (Perret 1976) show the airblast at the nearest house to be less than 0.0002 psi. This is two orders of magnitude less than the 0.029 psi that is used as the threshold for window breakage (less than 1 in 10,000 broken) (Siskind and Summers 1974).

Figure 9 gives a theoretical curve of overpressure versus range for a 75,000 lb deeply buried charge (Perret 1976). It shows that at greater than 1000 ft from the detonation, the expected pressure will be less than 0.006 psi. Due to the deeply buried nature of this experiment it is anticipated that even on the ground surface directly over the charge, the overpressure will be much less than 1 psi. Damage to life forms does not occur below 1 psi. By

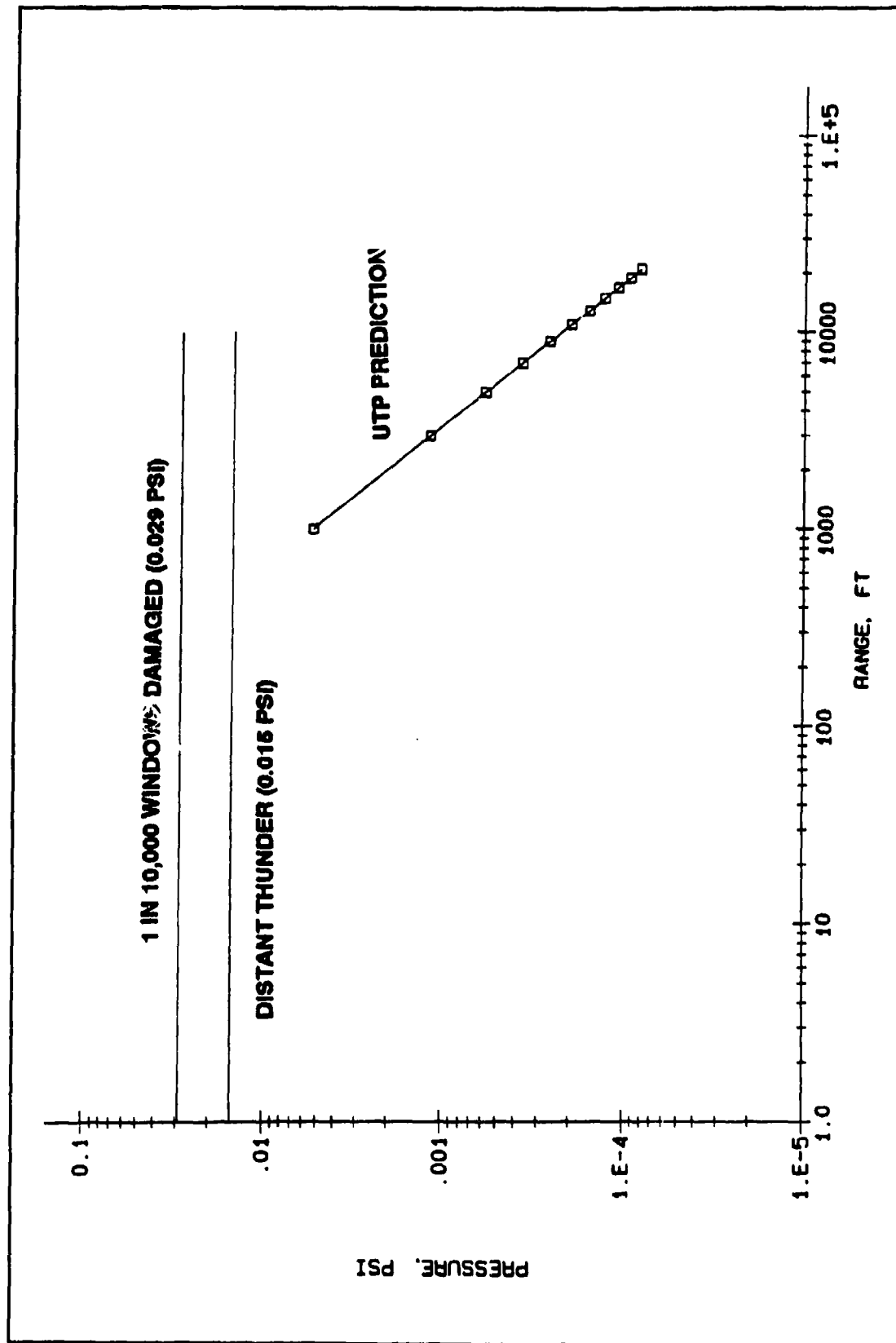


Figure 9. Overpressure vs. Range for deeply buried 75,000 lbs TNT equivalent

clearing an area of 2,500 foot radius of unprotected personnel before each test, there will be no danger to humans or other animals.

**Environmental effects of airblast and noise.** Based on the airblast and noise predictions above, no adverse environmental effects will be caused by airblast from this event. Noise at the nearest habitation (17,000 feet north) should be slightly audible, and the pressure will be orders of magnitude below structural damage thresholds (0.029 psi) and standards for impulsive noise established for the human ear (Iverson 1968 and U.S. Environmental Protection Agency (1974).

**Airblast and noise mitigation.** No measures to mitigate noise will be required. Due to the deeply buried test, weather will not be a factor. The test will be conducted during normal working hours.

### Ground shock

**Ground shock predictions.** Numerous methods for predicting long range ground shock produced by confined explosions have been developed. Nearly all of these are empirical, and are derived from curve fits to selected bodies of data. Reference 22 presents such an analysis, and gives two equations relating peak radial particle velocity, explosive weight, and distance. These equations are given below, where  $U$  is the velocity in inches/second,  $W$  is the explosive weight in pounds, and  $R$  is the range in feet:

$$U = 102.4 (R/W^{0.4})^{-1.33} \quad (1)$$

$$U = 53.1 (R/W^{0.5})^{-1.34} \quad (2)$$

Equation 1 is presented as a "best fit" to the data analyzed, and has often been used to predict ground shock effects on testing programs. Equation 2 is a fit to the same data, but utilizes "square root" scaling ( $W^{0.5}$ ), a system more common in analyzing mining/quarrying data. These two equations give roughly equivalent results for explosive weights of 200 lb; at greater weights, Equation 2 predicts increasing larger velocities than Equation 1, and hence is more conservative. Equation 2 is used for UTP estimates of ground motion, and is plotted in Figure 10 for explosive weights of 8,000, 20,000, and 75,000 lb of TNT equivalent. Since the charge weights for the four scheduled UTP events will increase sequentially, seismic measurements on each event will provide for refining the predictions to reflect coupling efficiency and the shock propagation characteristics of the Louisville Limestone.

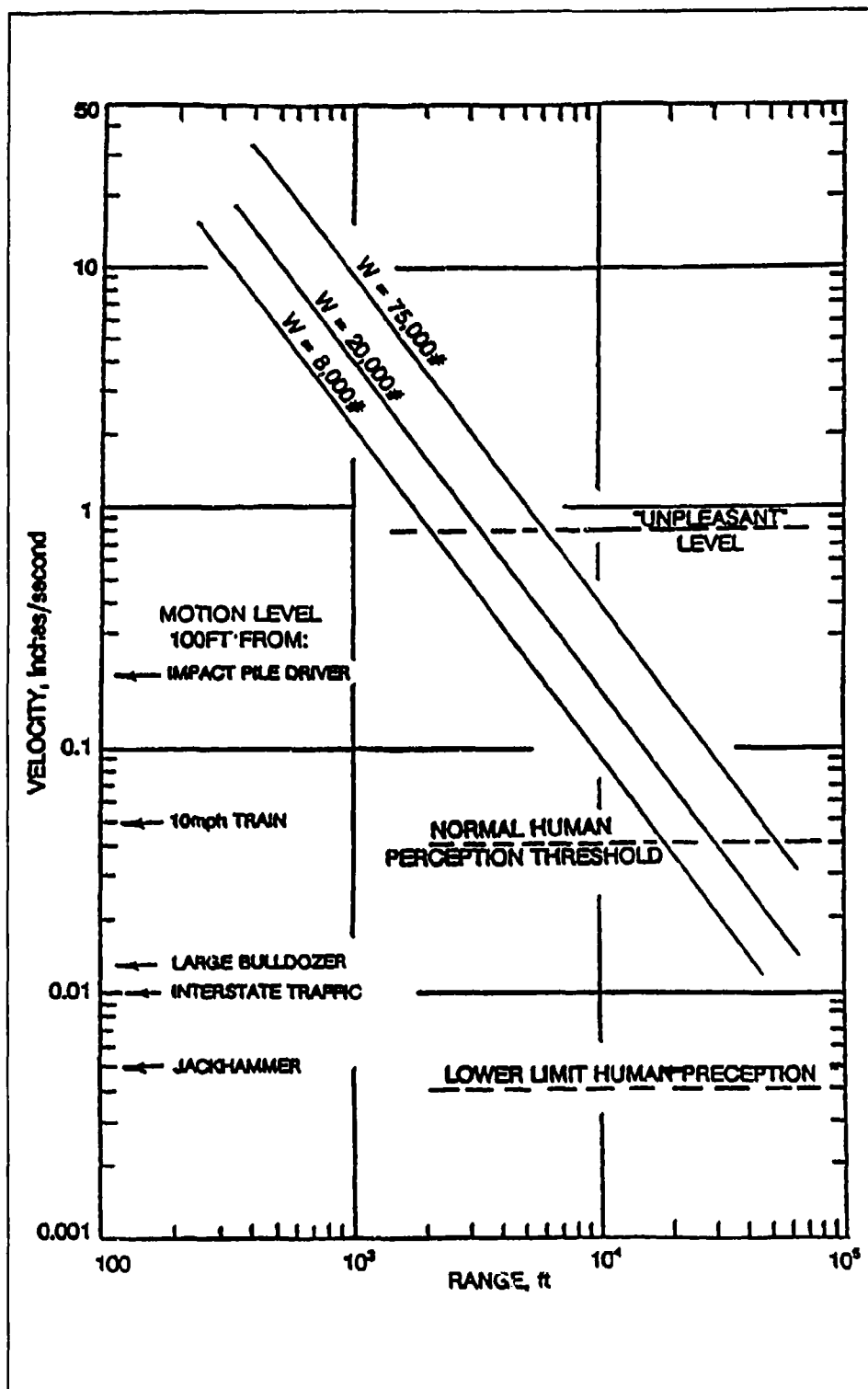


Figure 10. Predicted peak particle velocity versus range for UPT

Three human perception thresholds are shown in Figure 10 for reference purposes. These are the absolute lower limit (0.004 in./sec), the normal perception (0.04 in./sec), and the unpleasant threshold (0.8 in./sec). Additional reference is shown by motion levels obtained at a distance of 100 ft from various construction and transportation activities.

Several large-yield explosive tests have been conducted at the UTP site in Rodgers Hollow where seismic data were recorded. None of these tests used fully-coupled, single-point charges; instead, they used distributed charges with earth berms, with a significant fraction of the charge partially or fully coupled. Nevertheless, no damage due to ground shock has resulted from any of these previous tests.

**Ground shock effects on structures.** Damage, or potential damage, to structures is properly a major concern of explosive blasting operations. Accordingly, it has received a great deal of attention, and numerous studies have produced sets of damage criteria, usually taking peak particle velocity as the significant parameter. These are remarkably consistent, and several of them are summarized in Table 3 for residential-type structures. These are drawn from (Cauthern 1964, Benson 1980, Langefors 1958, Nicholls 1971 and McPerson 1980).

From the data in Table 3, a composite summary has been constructed and is presented in Table 4, together with the ranges at which several damage criteria are met for the UTP 37.5 ton (TNT equivalent) event (from Figure 10). Table 4 predicts no damage to residential structures beyond 5,000 ft. The nearest residential structure is just outside the north boundary of Ft. Knox, at a range of 17,000 ft NNE of the UTP event. No damage is expected at this range, where a peak velocity of 0.2 in./sec is predicted.

Other structures are, or will be, located within the Ft. Knox Military Reservation at ranges of a few thousand feet of the UTP site. In particular, a metal building, known locally as the "Tank Barn," is located on Ridge Road about 6,600 ft NE of the UTP site. The predicted velocity at this range is about 0.9 in./sec. (Atlas Powder Company 1987) suggests 60 in./sec for the threshold of major damage to pre-fabricated metal buildings on concrete pads, indicating that they are significantly less susceptible to damage than residences. No damage to the metal building is expected. Several trailers will be located at the UTP trailer park located about 3,000 ft SW of the UTP events, at a predicted velocity level of 2 in./sec. These trailers will be standard over-the-road freight trailers, with rugged frame and suspension systems. Johnson 1971, suggests a damage threshold of 120 in./sec for such trailers when parked on styrofoam or other shock mitigation systems. Cauthern, reports that "trailers" have withstood up to 6 in./sec with no damage. Similar trailers have been used on previous tests at similar scaled ranges, and have withstood airblast shock impacts of nearly 1 psi, with no damage.

Table 3 Damage Thresholds from References					
	Damage Threshold, in./sec				
Damage Type	Ref. 23 and 24	Ref. 25	Ref. 26	Ref. 27	Ref. 28
None	1.75	1	--	--	--
Opening of old plaster cracks	2	--	4.3	2-4	--
Fine plaster cracks	3	--	6.3	4-7	5.4
Plaster and masonry wall cracking/minor structure	--	--	9.1	> 7	7.6
Major structural damage/serious cracking	4.5				

Table 4 Composite Damage Criteria and Ranges at Which Criteria are Met for UTP 37.5-Ton Event		
Damage Type	Threshold, in./sec	Range at Which Criteria are Met, ft
None	1	5,000
Cosmetic	2	3,000
Minor structure	5	1,600
Major structure	7	1,200

Subsurface structures, such as basement walls, wells, and pipelines have been shown to be undamaged at velocities of less than 3 in./sec (McPherson 1989). This level will be attained at a range of 2,400 ft for the UTP test. No such structures are within this range.

Mechanical equipment, such as engines, pumps, compressors, generators, etc., mounted on skids and tied down, have damage thresholds of 40 in./sec (Atlas Powder Company 1987 and Johnson 1971). This level will occur at a range of about 350 ft. No equipment of this type will be closer than 3,000 ft.

Communications equipment, electronics, and computers with solid state components can withstand acceleration levels of 5 g (Schuster, Sauer and Cooper 1987). Substantial amounts of these types of equipment will be located at the UTP trailer park where ground accelerations of about 1 g are

expected. Since such equipment will be mounted in shock-isolated racks, no damage will occur.

**Ground shock effects on humans.** The threshold of human perception of ground vibration is significantly lower than the levels associated with the onset of structural damage. Subjective human response to vibratory ground motion, based on earthquake studies, has shown motions of 0.004 in./sec amplitude to be the absolute lower limit of human perception, and amplitudes of less than 0.04 in./sec are rarely perceived for short-period, explosion-produced motions (Ristvet 1987). These thresholds are indicated on Figure 10, and show that the limit of normal perception (0.04 in./sec) should occur at 55,000 ft, or approximately 10.5 miles, from the UTP structures event. The absolute lower limit of perception (0.004 in./sec) falls at a range of about 300,000 ft, extrapolating the curve of Figure 10, or at about 58 miles. Ristvet 1987, suggests a threshold of 0.8 in./sec for motions perceived as "unpleasant," and Siskind, Crum and Plis 1990, gives 0.7 in./sec as the level of "discomfort," or producing a "startle" effect. The 0.7 in./sec threshold is attained at a range of 6,500 ft from the UTP site.

Siskind, Crum and Plis (1990), lists thresholds of 2.2 in./sec and 4.4 in./sec for onset of interference with activity or proficiency, and health limit, respectively. These levels occur at 2,800 and 1,700 ft from the UTP site.

Table 5 summarizes these thresholds, together with the ranges at which they will occur from the largest UTP test. From this table, it can be seen that human perception may be possible at a range of 55,000 ft. This range includes the densely populated areas of Shepherdsville and the cantonment area of Ft. Knox, although motions at these locations will be well below the "unpleasant" threshold. A significant mitigating factor is the fact that the UTP events will be conducted during the day. Siskind, Crum and Plis (1990), indicates that human tolerance increases dramatically during periods of normal activity at home or in the workshop or office. For example, the tolerance level increases from 0.008 in./sec at night to 0.5 in./sec during the day, an

<b>Table 5 Motion Thresholds for Human Tolerance</b>		
<b>Subjective Criteria</b>	<b>Velocity, in./sec</b>	<b>Range at which Criteria Met, ft</b>
Absolute limit of perception	0.004	300,000
Normal perception limit	0.04	55,000
Unpleasant/ disturbing	0.7	6,500
Proficiency/ activity interference	2.2	2,800
Health/safety limits	4.4	1,700

increase of more than 60-fold. As a result, the UTP events may not be noticed outside the FKMR.

Disturbance complaints from people not expecting the ground motion are possible at levels of 0.1 in./sec (Siskind, Crum, and Plis 1990) and likely at levels  $> 0.2$  in./sec (McPherson 1989) even though no damage would occur.

These criteria are met at 28,000 and 17,000 ft, respectively. Numerous residences are located at less than 28,000 ft, especially to the north and east of the UTP site, so some complaints or inquiries are to be expected. Reference 33 suggests that prior publicity is effective in reducing or eliminating such complaints.

No humans other than those directly involved in the UTP tests will be within the radius of "unpleasant" ground motion (6,500 ft). None will be within the radius of health safety limits (1,700 ft). Those persons at the UTP trailer park, at a range of 3,000 ft, will be controlling and expecting the detonation and, hence, the "startle" effect will not be a factor. Suitable precautionary measures, such as stowing loose objects, will preclude any safety hazards at this location.

**Ground shock effects on biota.** Studies specifically designed to determine the effects of ground shock on subsurface animals, plant roots, and soil microbes show no damage by shock fronts whose peak particle velocities are less than 4.5 in./sec (Newcombe 1965 and Newcombe 1966). This level will be reached at a range of 1,700 ft from the UTP test. There exists some possibility of subterranean damage to root systems of flora within this radius, although for non-cratering tests significant permanent damage is unlikely. Merrit (1978), reports no important damage to tundra grasses for the CANNIKIN and MILROW tests on Amchitka Island, Alaska, at surface particle velocities of nearly 360 in./sec. Peak surface velocity for UTP will be on the order of 20 in./sec.

Subjective summaries of the effects of ground motion produced by underground tests on large mammals (deer, cattle, and horses) indicate no physical injury at peak velocities of up to 12.5 in./sec (Smith 1973). The whitetail deer is the only large mammal indigenous to the test area, and site activities will have driven these from the 800-ft radius for 12.5 in./sec velocity.

**Ground shock effects on surface geology.** There will be no significant effects on surface geological features in the vicinity of UTP in the form of cracking, spalling, or cratering.

The threshold of acceleration which can trigger minor rock slides is approximately 0.02 g's (Cauthern 1964). This value corresponds to a velocity of about 0.06 in./sec at a frequency of 30 Hz, and is expected at a range of 40,000 ft. From Figure 10, it is noted that this motion level is about that occurring 100 ft from a train. Two areas exist where there is a possibility,



however remote, of triggering minor rock slides. These are the steep hillsides along Highway 44 west of Shepherdsville, at a range of about 26,000 ft, and the cuts along Mt. Eden Church road on the Ft. Knox reservation about 14,000 ft NW of the site. Any such slides would be of the type periodically triggered by rain or traffic. Existing road conditions at both areas allow for safe accommodation of minor slides.

Examples of minor rockslides are cited in the literature, but are noted to be at substantially lesser ranges than suggested above. For the GASBUGGY event, of 26-kt yield, rockslides were noted in a road cut 4.7 miles from the test (Foote, Hays, and Kiepinger 1969). Using cube-root scaling, this translates to a range of 0.53 miles (2,800 ft) for UTP. The RULISON event, of 40-kt yield, caused some minor rockfall and slides at a range of 4.4 miles (Foote, et al 1970). This scales to 0.43 mile (2,270 ft) for UTP. It thus appears that the 40,000 ft estimate given above is extremely conservative, and that no rockslides are likely beyond a few thousand feet.

There are several small (from a few to about 20 acres) ponds on the Ft. Knox reservation at ranges of about 12,500 ft to 26,000 ft to the east of the UTP site. Most of these are impounded by small earthen dams of inferior to moderate quality. No construction details are available, but the dams appear to have been constructed from local borrow material, most likely clays or riverine silt. The dams, and impounded water, are shallow. Some of the dams are "leaky."

Potential failure of dams from explosively-produced ground shock (or earthquakes), especially where such failure would have catastrophic consequences, has received much consideration. The most probable mechanism of failure would be soil liquefaction, a condition possible only in fine-grained, cohesionless soils which are loose and saturated (Means and Parcher 1963). (Means and Parcher 1963) suggests that liquefaction failure is dependent on a "collapsible soil structure," that is, a soil with (a) less than 10 percent fines (passing a No. 200 sieve), (b) an effective grain size ( $D_{10}$ ) of between 0.05 mm and 1.0 mm and (c) a uniformity coefficient of 2 to 10. No soil analysis of the dam material has been made. However, it is unlikely that it differs greatly from other valley or "hollow" soils in the northeastern part of the Ft. Knox reservation, since the source materials are limestones and shales throughout the area. Both of these weather to clays. The near-surface soil in Rodgers Hollow is described as a "brown, gravelly clay," classification CL, and has 59 percent fines, a  $D_{10}$  of 0.002 mm, and a uniformity coefficient of 50 (Gilbert 1976). Thus, Rodgers Hollow soil would not be subject to liquefaction, and by extension, the earthen dam material would not be susceptible to such failure.

A major failure due to liquefaction occurred in the San Fernando Dam in California as a result of ground motions produced by the earthquake of February 1971 (Cargile and Kean 1988). In this case, the material was sandy, with a  $D_{10}$  of about 0.1, and a uniformity coefficient of 7 to 10. In addition, the recorded motions were high, about 10 in./sec. Since the

expected motions from UTP at the nearest dam (12,500 ft) are about 0.3 in./sec, and since the soils do not appear to be candidates for liquefaction, no damage (failure or partial failure) is expected.

**Potential seismic zone activation.** There exist several active seismic zones in the Central Mississippi Valley region of the United States. Most notable of these, and the only one known to have generated earthquakes which caused widespread structural damage, is the New Madrid Seismic Zone. This zone lies along, and about 25 miles to either side of, a line running approximately from Marked Tree, Arkansas, to Metropolis, Illinois. The closest boundary of this zone lies about 155 miles southwest of the UTP Test Site at Ft. Knox, KY. Figure 11 outlines the location of the New Madrid Seismic Zone (Saint Louis University 1990).

Historically, there has been considerable interest in, and study of, seismic activity induced by underground (i.e., fully contained) explosions, especially nuclear detonations. Detonations at the Nevada Test Site and on Amchitka Island, AK, have been studied extensively for possible correlation of detonation energy release and subsequent seismic events. Both of these areas are in regions of substantial seismic activity; Amchitka, in particular, is in one of the world's most seismically active areas.

The MILROW and CANNIKIN nuclear events were conducted on Amchitka in 1969 and 1971. Exact yields of these events remain classified, but are listed in unclassified literature as "about 1 MT" and "less than 5 MT," respectively, where 1 MT refers to the energy release of one million tons of TNT (Merrit 1978). Seismic data were gathered both pre- and posttest for both of these events. For the MILROW event, 12 tectonic aftershocks (as opposed to aftershocks associated with cavity collapse) were recorded, and were all of magnitude less than three. After the CANNIKIN test, 22 tectonic events were recorded; all were of magnitude less than four and all occurred within a few miles of the CANNIKIN test. The seismic stations for the CANNIKIN test had been monitored for a considerable time prior to the test. Figure 12 presents the cumulative number of events of magnitude three or greater within a radius of 31 miles of the test, beginning in 1970. In the 22 months prior to CANNIKIN, there were roughly 260 such events; from Figure 12, it is obvious that no increase in the rate of occurrence of such events was noted as a result of the CANNIKIN test. It may further be inferred from Figure 12 that most of the 22 events mentioned above were of a magnitude less than three and, hence, do not appear on the graph. Saint Louis University (1990), concludes that "it appears that the effects of CANNIKIN were much too local to have any effect on regional seismic activity."

Similar conclusions have been reached for nuclear detonations at the Nevada Test Site. Five detonations in the 1 MT range were conducted beneath Pahute Mesa between 1966 and 1970, and seismic activity associated with them has received a great deal of scrutiny. It has been found that very few aftershocks occurred beyond 12 miles from the detonation, and none was found beyond 25 miles (Glasstone 1971). A statistical study of

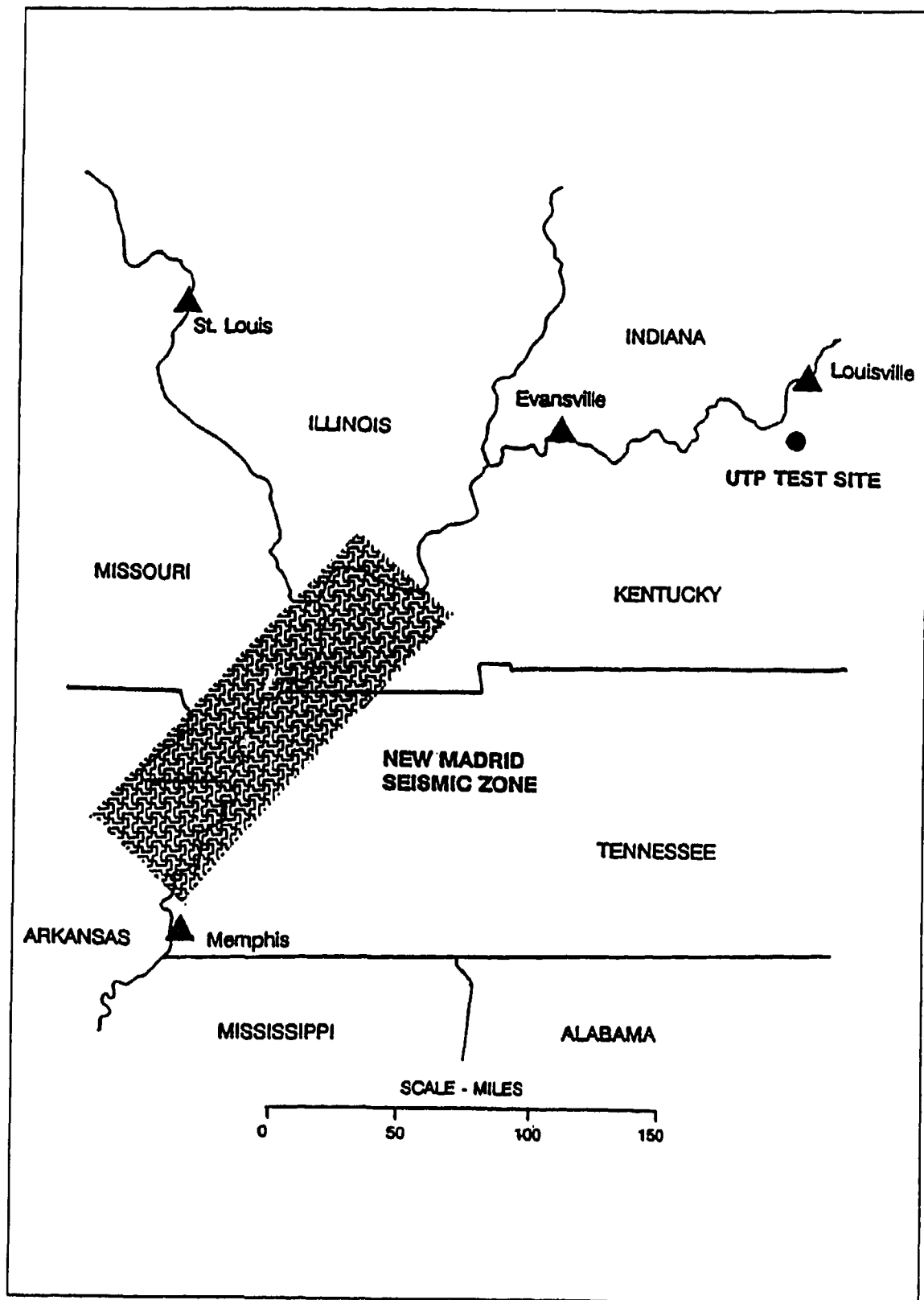


Figure 11. Location of the New Madrid Seismic Zone

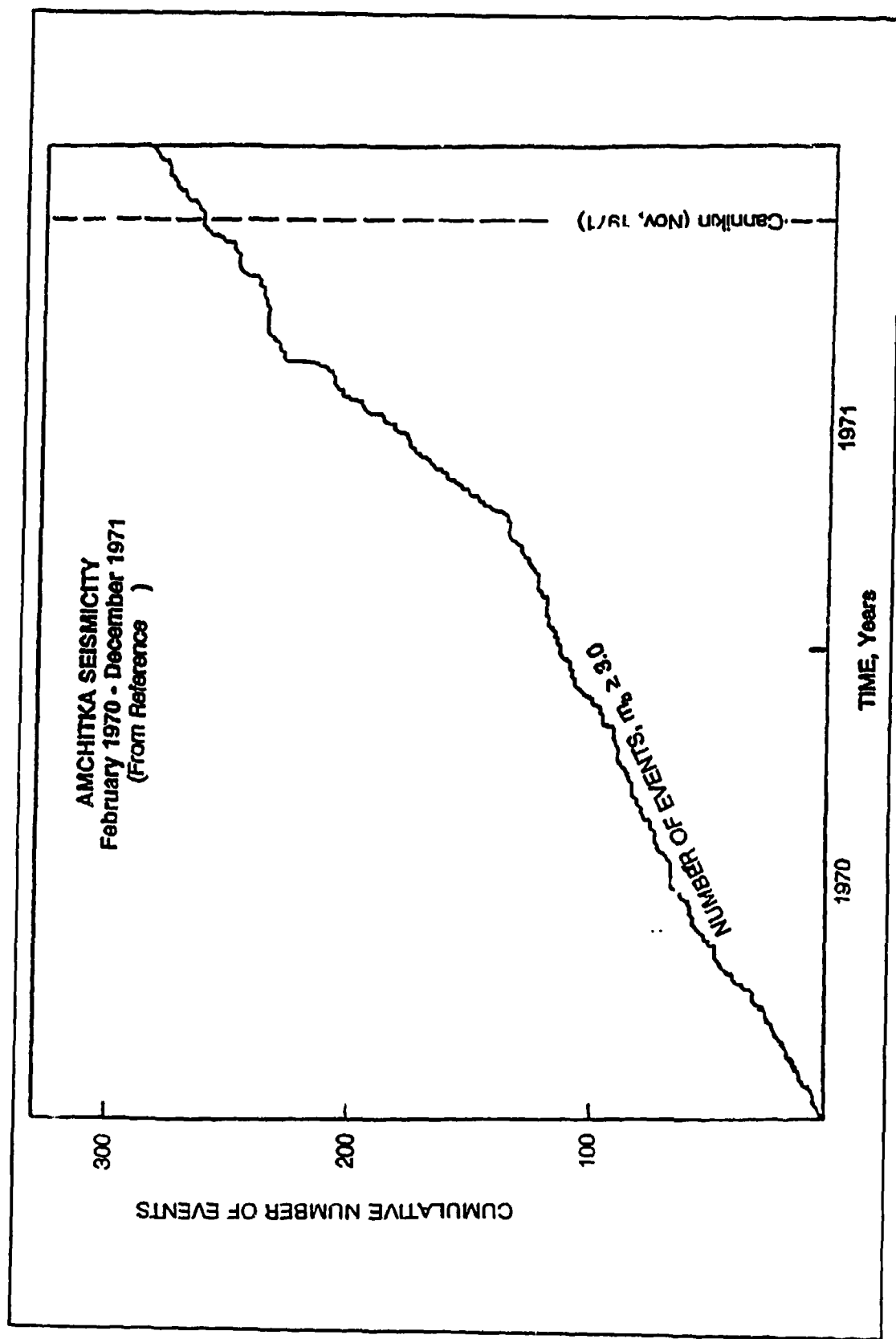


Figure 12. Cumulative seismic activity on Amchitka Island, 1970-1971

235 underground explosions has been made for periods of 104 hours prior to, and after, the events, and for a radius of 535 miles from the Nevada Test Site. This radius includes the dangerously active San Andreas Fault in California. The total seismic events occurring were 620 for the preshot periods, and 616 for the postshot periods. Siskind, Crum and Plis (1990), concludes that "there appears to be no correlation between underground nuclear explosions and natural earthquakes in the area under consideration."

A "rule of thumb" has been developed, based on the above-mentioned studies, to predict the maximum range for displacement along a fault line to occur, a prerequisite for earthquakes. The "rule" estimates the range to be 1,000 times the cube root of the explosive yield, expressed in kilotons of explosive, or  $R = 1,000 \times (KT)^{1/3}$  (Glasstone 1971). Since the largest planned UTP event will be 37.5 tons, or 0.0375 KT, this "rule" gives a maximum range for fault displacement to occur of 336 feet.

Not only have the tectonic events associated with large yield nuclear detonations been few and extremely local, as described above, but are always minor relative to the initial disturbance itself. The largest reported have had energy releases of only a few percent of that of the causative detonation (Glasstone 1971).

Numerous significant energy inputs have occurred, and continue to occur, in the Central Mississippi Valley without triggering activity in the New Madrid Seismic Zone. Figure 13 shows locations of seismic events (earthquakes) occurring in this region between July 1974 and March 1990 (Saint Louis University 1990) and differentiated by magnitude. More than two dozen earthquakes of magnitude three or greater have occurred in less active seismic zones adjacent to the New Madrid in Arkansas, Missouri, and Illinois. No cause/effect relationship has been cited. For perspective, an approximate relationship between energy release, expressed in tons of TNT equivalent, and body wave magnitude, is presented in Figure 14 (extrapolated from Merrit 1978). It can be seen that the largest UTP test, of 37.5 tons, will produce a body wave magnitude of roughly 2.6. Since an increase in one magnitude unit is approximately equivalent to a 30-fold increase in energy, the magnitude 5 earthquake shown in Eastern Illinois on Figure 13 represented an energy input more than 2,500 times that of the planned UTP Event. No destructive activity in the New Madrid Zone followed.

Other major sources of ground shock energy are coal mining/quarrying operations common in the Illinois/Indiana area. One example is located about 10 miles northeast of Evansville, IN. Here, large yield detonations of up to 325,000 lb of explosive are conducted often at the rate of several per day (Siskind, Crum, and Plis 1990). Although the detonations consist of individual charges of a few hundred to about 7,000 lb, initiated sequentially to minimize vibrations at nearby structures, the entire charge is fired in slightly over one second. Thus, each shot represents a significant energy input. No seismic events in the New Madrid, or other zone, have been connected to these events.

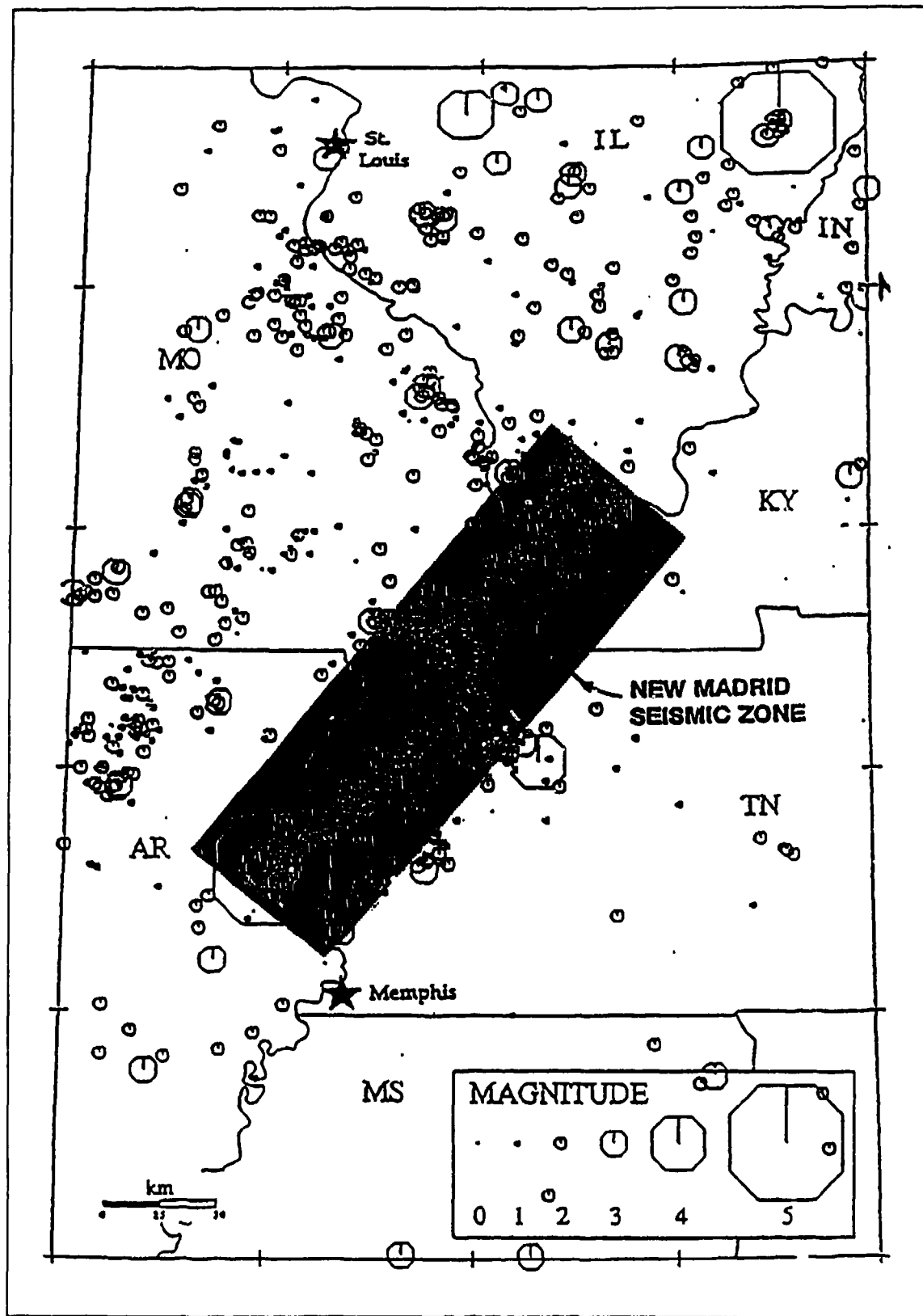


Figure 13. Seismic activity in the Central Mississippi Valley, 1974-1980

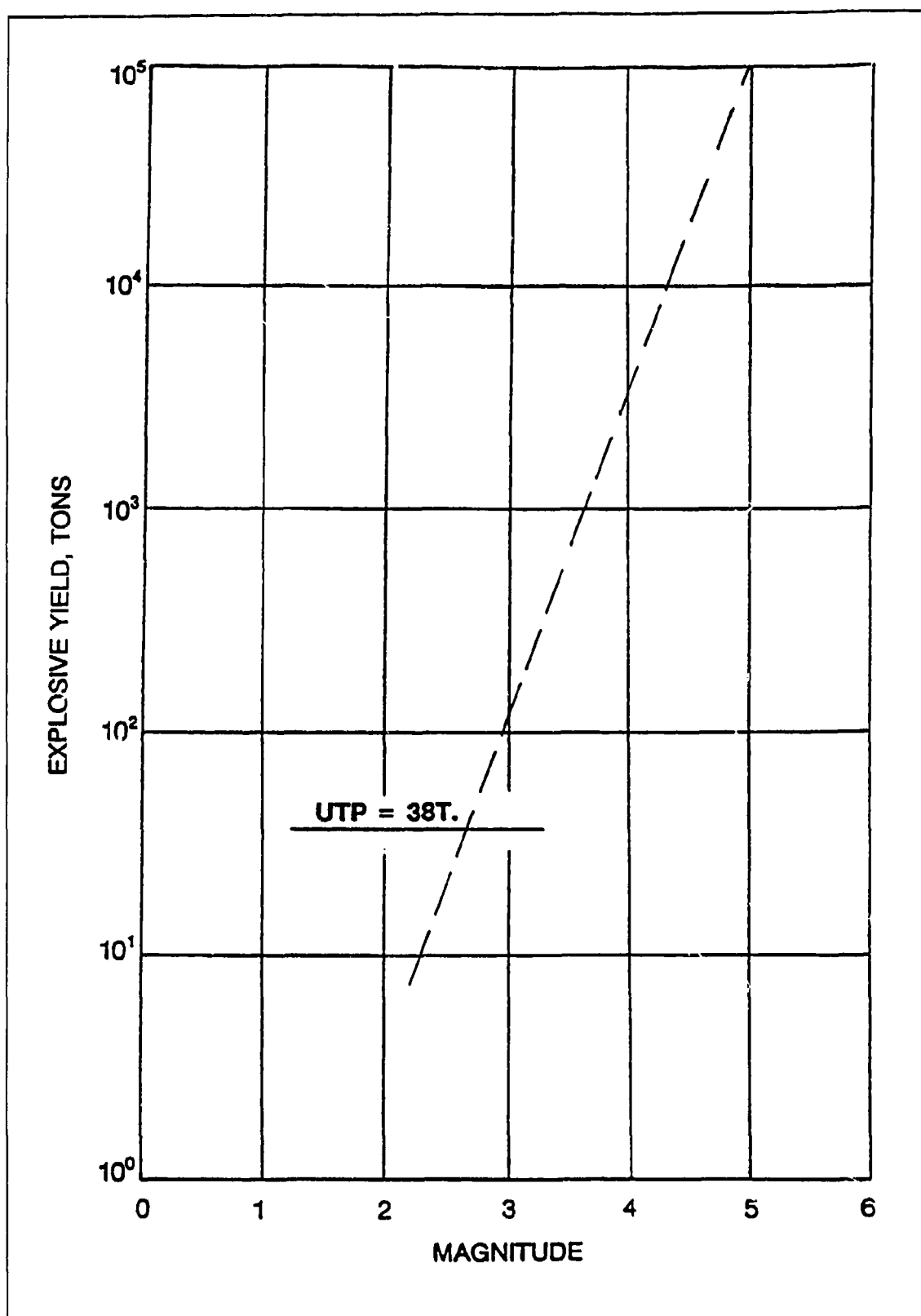


Figure 14. Approximate relationship of explosive energy yield versus magnitude

Based on the above data, the likelihood of inducing regional seismic activity by the UTP is judged to be nil. The 37.5-ton energy yield is far too small to cause even the very local and minor aftershocks sometimes observed on MT-range nuclear events.

### **Cratering and ejecta**

**Crater predictions.** Explosive detonations have been shown to be fully contained, i.e., do not produce ejecta craters, at scaled depths of burial  $(D/W^{1/3})$  greater than four, where  $D$  is in feet, and  $W$  is the charge weight in pounds. For the UTP Structures test, the nominal depth of burial will be about 575 ft, and the charge weight will be 75,000 lb (TNT equivalent). This gives a  $D/W^{1/3}$  of 13.6, or more than three times the fully contained situation. No surface crater will therefore be produced by the UTP tests.

**Ejecta.** Since there will be no crater formation, there will be no ejected material in the sense of particles thrown out by expanding detonation gasses. There is a remote possibility of dust and small, loose particles being lofted slightly (perhaps a few feet) in the region immediately above the shot point. However, no surface mounding, cracking, or spallation will occur.

### **Charge cavity and fracture zone**

The pressures generated by the detonation will be on the order of 125 kbar (nearly 2 million psi). This intense pressure will deform the rock mass surrounding the charge through compressive and shearing action, and will accelerate the rock particles away from the detonation point. Some of this deformation will be plastic (permanent), leaving a void, or cavity, at the detonation point.

Based on two-dimensional calculations for UTP (Rocco 1991), the residual cavity for the structures test is estimated to be 12.3 ft in radius, and roughly spherical. The initial charge radius will be about 6.3 ft. Thus, the cavity radius will be about twice the charge radius. Cavity radii estimates for the CAL-2 and CAL-3 tests (8,000 lb TNT equivalent for each) and the UTP Large Scale Cal test (20,000 lb TNT equivalent) are 5.9 ft and 7.9 ft, respectively.

Studies of cavities generated by contained nuclear explosions in medium- to high-strength rock have yielded empirical estimates of cavity size. One such estimates gives the scaled cavity radius  $(R/KT^{1/3})$  as 29.5 to 52.5, where  $R$  is the radius in feet and  $KT$  is the energy release in kilotons (Reference 50). These bounds correspond to "strong" and "weak" rock, respectively. For the UTP 37.6 ton (0.0375 KT) structures test, and using a scaled radius of 40, this relationship predicts a cavity radius of 13.4 ft. This is in good agreement with the estimate of (Rocco 1991).



For a considerable distance beyond the boundary of the residual cavity, the rock will be highly fractured. Data in (Drake, Blouin and Ingram 1984) shows the fracture zone to extend to a radius of three to five times that of the residual cavity. Using the more conservative ratio of five, rock fracturing may be expected to extend to a radius of 61.5 - 67.0 ft for the 37.5-ton event. This range corresponds to a predicted stress level of about 2.2 kbar (Rocco, Williams and Thomsen 1990). Since (Rocco 1991) suggests that the fracture zone for "medium strength" rock would extend to the 5 kbar stress level, the radius predicted here is probably an upper bound. For the 20,000 lb and 8,000 lb events, the radii for fracture are 39.6 ft and 29.2 ft, respectively.

### **Detonation products**

The gaseous products of detonation of high explosives or blasting agents generally contain, to various degrees, small quantities of substances known to be hazardous to the environment. Some explosives produce more of these products than others. Unfortunately, some of those most desirable from the standpoints of energy content and ease of placement are among those which could be environmentally controversial. As a result, considerable attention has been given to selection of candidate explosives for the UTP experiments which will meet both project requirements and environmental constraints. The two candidates, Pourvex and QM-100, are considered "clean" and should pose no environmental hazard.

Prediction of detonation products. Two methods, laboratory tests and computer calculations, are used to determine the chemical products of detonation. Limited laboratory test data exists for a few explosives, such as TNT, HMX, and nitromethane. For the most part, however, reliance has been on the results of thermodynamic/hydrodynamic equilibrium calculations (Chaiken, Cook, and Ruhe 1974 and Renner and Short 1980). These calculations use thermodynamic/hydrodynamic equilibrium codes, such as TIGER, developed by the U.S. Army Ballistics Research Laboratory, Aberdeen Proving Ground, MD; RUBY, used by Livermore National Laboratory, Livermore, CA; and HT-65, used by Explosives Technologies, Inc., and its predecessor, E. I. DuPont. Such code predictions of detonation products are relied upon heavily by the U.S. Bureau of Mines (USMB), and the Department of Defense (DOD). These code predictions are used herein to provide the detonation products for QM-100 (using TIGER) and POURVEX (using HT-65).

Table 6 lists detonation products for 1,000 pound charges of POURVEX and QM-100. Table 6 shows that essentially all of the net weight for QM-100 is accounted for, while for POURVEX approximately 0.2 percent is missing in the calculation. It is likely that the missing component is Formic Acid, which shows 1.66 pound per 1000 pounds in the QM-100 list, and is also present in a similar ETI formulation named TOVEX EXTRA, at the rate of 0.47 pounds per 1000 pounds.

**Table 6**  
**Calculated Detonation Products of Candidate Explosives/**  
**1000 Pounds**

Compound	Formula	Amount Produced by 1,000 Pounds	
		QM-100	POURVEX
Water	H <sub>2</sub> O	530.64	497.782
Nitrogen	N <sub>2</sub>	253.12	234.494
Carbon Dioxide	CO <sub>2</sub>	173.36	153.595
Carbon Monoxide	CO	2.83	12.605
Ammonia	NH <sub>3</sub>	16.52	3.747
Carbon (solid)	C	--	--
Hydrogen	H <sub>2</sub>	0.79	2.117
Oxygen	O <sub>2</sub>	--	--
Methane	CH <sub>4</sub>	10.51	0.963
Ethane	C <sub>2</sub> H <sub>6</sub>	--	--
Hydrogen Cyanide	HCN	--	--
Formic Acid	CH <sub>2</sub> O <sub>2</sub>	1.66	7
Nitric Oxide	NO	--	--
Nitrogen Dioxide	NO <sub>2</sub>	--	--
Nitrous Oxide	N <sub>2</sub> O	--	--
Silicon Dioxide	SiO <sub>2</sub>	9.90	--
Sodium Carbonate	Na <sub>2</sub> CO <sub>3</sub>	--	84.803
Sodium Silicate	Na <sub>2</sub> SiO <sub>5</sub>	--	7.704
TOTALS		999.33	997.81

Inclusion of 1.5 pounds of formic acid would bring the POURVEX calculation to the same degree of accuracy as that for QM-100.

The planned explosive weight for the UTP Structures Test is 75,000 pounds (37.5 tons) of TNT equivalent explosive energy. Both of the candidate explosives under consideration have substantially less energy release, in calories/gram, than TNT, so that about 112,831 pounds of POURVEX or 120,094 pounds of QM-100 will be required for an equivalent simulation. Table 7 lists detonation products for the two explosives for the estimated weights of each, along with the Comprehensive Environmental Recovery Compensation, and Liability Act (CERCLA) reportable quantities (RQ) for hazardous substances.

For both explosives listed in Table 7, none of the products with RQ's of 10 pounds (HCN, NO, NO<sub>2</sub>) is predicted to be present. Formic acid is present at levels of less than 200 pounds, or 4 percent of RQ. Ammonia, however is present in an amount of 1,982 pounds for QM-100, and 450 pounds for POURVEX, and exceeds the RQ by a substantial margin. Mitigating circumstances for release of this substance are discussed below.

**Detonation product effects on groundwater.** All of the detonation products listed in Table 6 occur naturally in the earth's environment. Extensive literature searches and contacts with personnel from the Bureau of Mines, WES, U.S. Geological Survey, U.S. Army Corps of Engineers, Naval Weapons Center, and other organizations involved in the use of high

<b>Table 7</b> <b>Calculated Detonation Products of Candidate Explosives</b>				
Compound	Formula	Amount Produced		
		QM-100 120,094 lb	POURVEX 112,831 lb	CERCLA RQ
Water	H <sub>2</sub> O	63726.7	56165.2	--
Nitrogen	N <sub>2</sub>	30398.2	26458.2	--
Carbon Dioxide	CO <sub>2</sub>	20819.5	17330.3	--
Carbon Monoxide	CO	339.9	1422.2	--
Ammonia	NH <sub>3</sub>	1983.9	422.8	100
Carbon (solid)	C	--	--	--
Hydrogen	H <sub>2</sub>	94.9	238.9	--
Oxygen	O <sub>2</sub>	--	--	--
Methane	CH <sub>4</sub>	1262.2	108.7	--
Ethane	C <sub>2</sub> H <sub>6</sub>	--	--	--
Hydrogen Cyanide	HCN	--	--	10
Formic Acid	CH <sub>2</sub> O <sub>2</sub>	199.4	169.2 <sup>1</sup>	5000
Nitric Oxide	NO	--	--	10
Nitrogen Dioxide	NO <sub>2</sub>	--	--	10
Nitrous Oxide	N <sub>2</sub> O	--	--	--
Silicon Dioxide	SiO <sub>2</sub>	1188.9	--	--
Sodium Carbonate	Na <sub>2</sub> CO <sub>3</sub>	--	9658.4	--
Sodium Silicate	Na <sub>2</sub> SiO <sub>5</sub>	--	869.3	--
TOTALS		120013	112753.2	

explosives indicate that significant contamination of groundwater by detonation products has never been observed. However, the amount of measured data is small, and none applies directly to contained underground detonations. Nevertheless, existing data is encouraging. Measurements of specific chemical compounds (for which water standards exist) were made from water and soil samples taken during other test programs. These include the PACE program, a series of explosive tests on a coral atoll over a fresh-water Gyben-Herzberg lens (U.S. Air Force 1973) and the MISERS BLUFF test program at Lake Havasu, Arizona (Perry 1979). In these tests, water and soil samples were collected and analyzed following the explosion of three 1,000-pound TNT charges which were partially buried in the coral soil and six 100-ton ANFO surface charges (MISERS BLIFF). EPA groundwater contamination standards exist for cyanide, ammonia, and nitrates. No significant concentrations were introduced into the groundwater by the explosion.

Analysis of both soil and groundwater samples from the 100-ton ANFO craters of the MISERS BLUFF test program show that the levels of cyanides were below the limit of detection, and the ammonia and nitrates were well within the concentrations permitted for drinking water (Reference 55).

Chemical analysis for explosive product contamination in the soil from the MIDDLE GUST crater (*Proceedings of the Mixed Company/Middle Gust Results Meeting* 1973) were performed without finding any chemical species which exceeded the levels found in control samples. However, analysis was performed only for total carbon, carbonate, organic carbon, sulfur, phosphorus, and nitrogen.

Analyses by the U.S. Geological Survey of the possible effects of the HAVE HOST test program on local groundwater resources (Wehro 1982) concluded that any possibility of groundwater contamination was extremely remote.

For the UTP detonations, Table 7 suggests that ammonia is the only potential hazard. Mitigating circumstances, however, indicate that the concern is academic rather than real, and that the potential introduction of ammonia into the groundwater presents no environmental hazard. These factors are:

a. The ground water available at Rodgers Hollow in the Louisville Limestone formation does not meet the EPA standards for a potential underground source of drinking water (USDW). These standards cite a maximum total dissolved solids (TDS) of 10,000 mg/l (United States Code of Federal Regulations 1990). Water from the Louisville limestone has shown a TDS of 16,500 mg/l (Water Quality Analysis 1991). Table 8 lists test results on this water. Further, national secondary drinking water standards cite a maximum contaminant level for iron as 0.3 mg/l and chloride as 250 mg/l (United States Code of Federal Regulation 1990). The groundwater analysis shows 6.0 mg/l of iron, and 11,535 mg/l of chloride. Thus, the local water in the Louisville aquifer is much too ferrous and saline to meet minimum standards.

Microbac

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Sample From: U.S. Army Engineer  
CEWES-CT  
3909 Halls Ferry Road  
Vicksburg, MS 39180-6199  
Attn: Steve Shore

Date Entered: 6-4-91

Reference: Fort Knox / P.O. #DACA3991M3373

Certificate of Analysis # 42043

Table 8. CB-6 WATER QUALITY (Continued).

ANALYSES	RESULTS
Conductivity	27,000 umhos
Dissolved Oxygen	0.7 mg/l
pH	7.01
Turbidity	225 FTU
Total Alkalinity CaCO <sub>3</sub>	456 mg/l
Chloride	11,535 mg/l
Aluminum	2.09 mg/l
Calcium	588 mg/l
Magnesium	336 mg/l
Potassium	62.1 mg/l
Sodium	5620 mg/l
Hardness (CaCO <sub>3</sub> )	2820 mg/l
NH <sub>3</sub> + NH <sub>4</sub> - N Total	20 mg/l
NO <sub>2</sub> + NO <sub>3</sub> - N Total	0.18 mg/l
Phosphorus	0.1 mg/l
Total Dissolved Solids	16,500 mg/l
Arsenic	0.16 mg/l
Barium	0.9 mg/l
Cadmium	<0.005 mg/l
Chromium	0.10 mg/l
Copper	0.08 mg/l
Iron	6.00 mg/l
Lead	<0.05 mg/l
Manganese	0.08 mg/l (continued)

Signed: K. W. Schmidt Date: JUN. 20 1991

# Microbac Laboratories, Inc.

**Kentucky Testing Laboratory Division**  
1121 West Broadway Louisville, KY 40203  
502/583-5256 502/589-6019 Fax: 502/589-0539

Sample From: U.S. Army Engineer  
CEWES-CT  
3909 Halls Ferry Road  
Vicksburg, MS 39180-6199  
Attn: Steve Shore

**Date Entered: 6-4-91**

Reference: Fort Knox / P.O. #DACA3991M3373

Certificate of Analysis # 40243

Table 8. CB-6 WATER QUALITY (Concluded).

[illegible]

**Signed:**

Karl W. Schmidt

Date \_\_\_\_\_

JUN. 20 1891

b. EPA standard for hazardous risk assessment for groundwater use have an "assigned value" of "0" for a distance of greater than 3 miles to the nearest well serving as a water source (United States Code of Federal Regulations 1989). The nearest inhabited dwelling is more than 3 miles distant. Further, U.S. Geological Survey water quality monitoring data do not list any wells penetrating the Louisville aquifer in the Ft. Knox area. Most of the listed wells draw from the St. Louis or St. Genevieve limestones, which lie above the Louisville formation in the geologic section. The St. Louis and St. Genevieve formations are missing in the Rodgers Hollow area, and thus inter-aquifer contamination is not possible.

c. Ammonia has EPA ratings of 3 for toxicity, 0 for persistence, 1 for ignitability, and - for reactivity (United States Code of Federal Regulations 1989). The toxicity rating of 3 indicates a severely toxic substance through inhalation, ingestion, or dermal contact. Ammonia is highly soluble in water, however, and its confinement underground will preclude such contact. More important is the "0" rating for persistence, which indicates an "easily biodegradable compound" (United States Code of Federal Regulation 1989). Therefore, groundwater contamination should be a short-term, and very local, consideration as the ammonia is reduced to harmless substances.

d. The potential generation of ammonia will be an instantaneous, discrete event occurrence rather than a continuous or repetitious injection. The UTP structures test will be preceded by three smaller calibration tests which will produce detonation products of roughly 10 percent, 10 percent, and 27 percent, respectively, of the amounts listed in Table 6. The total of four events will occur at intervals of about one year. The possibility of cumulative contamination therefore does not exist.

Based on the above mitigating factors, it is concluded that the UTP explosions will not generate toxic substances which will pose either a short-term or long-term environmental hazard through degradation of groundwater quality. Nevertheless, compliance with EPA regulations regarding pretest permitting and/or posttest reporting will take place as required, based on the anticipated generation of ammonia in excess of the RQ.

**Detonation product effects on air quality.** The deeply buried and fully contained nature of the UTP experiments will preclude any significant degradation of air quality. The high detonation pressures and intense local deformation close to the explosive charge will close the small access pipe within a few milliseconds of the detonation. No more than a very small fraction of the detonation gases will escape prior to closure and these will dissipate quickly through the adit ventilation system. The oxygen-balanced explosives produce no solid carbon (smoke), so there will be no visible effects. The overall effect on air quality will be far less than occurred on previous tests at Ft. Knox, or that occurs on common mining/quarrying operations in the Kentucky/Indiana area.

## **Ecological Consequences**

Vehicular use in the areas investigated will have a temporary, minor adverse effect on the environment. A small amount of vegetation and wildlife habitat will be destroyed or damaged along vehicle pathways. There will be some disturbances due to minor off-road driving for exploratory drilling and seismic surveys within the proposed test bed. A few individuals of some wildlife species may be killed as a result of traffic through these areas. This loss will not result in any long term reduction in population levels.

Posttest, the disturbed ground caused by construction will be filled and leveled, and construction debris removed from the test site; vegetation will be allowed to re-establish naturally after immediate reseeding with native grasses. Recovery of disturbed areas is correlated with the productivity of the vegetation. Loss of this vegetation represents a temporary decrease in the amount of food available to wildlife in the immediate vicinity of the test site.

Preparation of the site will displace or possibly kill the burrowing rodents which inhabit the area. Nonburrowing animals will move to undisturbed areas. Approximately ten small rodents and six to ten rabbits may be involved in this habitat disruption. Larger animals will shun the test area until after the test. Care will be taken to ensure that apparent animal trails are not blocked. Bird census estimations indicate that the test area now supports about 0.3 birds per acre. Assuming that only birds from the cleared area are displaced, a maximum of ten birds will be affected.

Human activity and machine noise associated with the construction will disturb wildlife and will alter the distributional pattern of some species for a short period; however, no long term effects will occur.

No animals will be injured due to airblast, directly or indirectly. Burrowing animals will probably have been displaced by construction operations during site preparation.

The proposed action will not result in any adverse effects to those endangered or threatened species of fauna or flora discussed in Chapter 1. Airblast will not reach pressures high enough to present a threat to animal safety. The detonations will produce a "startle" effect from the noise and ground shock levels at distances up to perhaps three miles. However, since Ft. Knox is used almost daily for tank and artillery missions, detonation noises at comparable magnitudes are not unusual.

## **Socioeconomic Consequences**

Effects on the socioeconomic environment due to construction and operations will not be significant. The site is remote. The work force is small, not expected to exceed 15 people at any time, and the total construction effort is



not large. The quartering of work force personnel will provide additional income to local motels in Shepherdsville, Kentucky. Local purchases of food, gasoline, hardware, building supplies, and services will provide a temporary increase in income for local businesses. The estimated total economic impact for the duration of the project will be the expenditure of \$3.3 million in the local area.

## **Geologic Consequences**

The major geologic consequence will be an increase in erosion potential due to the surface disturbance caused during construction. The increase in erosion potential arises for the changed nature of soils affected. Because of the small surface area involved and the use of engineering methods to control erosion due to surface disturbance, the increase in erosion potential will not be significant.

The water table directly above the test bed may be temporarily disturbed by the test. The area affected will be a few acres at most. The phreatic surface will reform within a matter of days after the test.

## **Historical, Archaeological, and Paleontological Consequences**

There are no known archaeological or paleontological resources within the proposed test area; hence, there is no potential for damage or destruction of such sites (Analytical/Environmental Assessment Report 1987).

An archaeological survey has not been conducted at the proposed test site. Although unlikely, should an archaeological site be discovered during construction, the test bed will be moved to avoid any disturbance to the site. This modification would be with the approval of the land administrator.

## **Consequences of the Proposed Action Which Cannot Be Avoided**

Consequences which cannot be avoided during the construction phase or as a result of the proposed detonation include:

- a. Temporary destruction or alteration of terrestrial ecological habitats.
- b. Temporary displacement of burrowing animals.
- c. Temporary and minor increase in erosion potential.

- d.* Temporary, minor, and extremely local deterioration of air quality due to construction activity.
- e.* Temporary and minor increases in ambient noise levels due to construction activity.
- f.* Temporary disruption of animal activity due to "startle factor" of ground shock from the detonation.
- g.* Temporary, minor and extremely local deterioration of water quality.
- h.* Consumption of explosive charge and fuel oil with associated detonation and combustion products.
- i.* Degradation of the aesthetic quality of the test site caused by surface disturbance during construction.

The construction activity and detonation will destroy the short-term productivity of some ecological habitats. This will not have a long-term impact on the productivity over the region because of the extremely small area affected. The net effects to the environment will be restricted to the immediate test site area. After the test program is completed, the area will be restored to as near its former condition as reasonably possible. All test construction will be dismantled and removed, and the entire test site will be cleared of debris. The test area will be regraded to former topographic contours. Shallow buried cables will be removed. The adit will be sealed with a twenty foot thick concrete "plug" to prevent further access.

The proposed tests will not foreclose any future options on use of the area. There are no short-term environmental gains associated with this project at the expense of long-term losses. The area will be disturbed for an estimated five-year period, after which the biota will begin its recovery cycle.

## 4 Agencies and Persons Consulted

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1. U.S. Army Engineer Waterways Experiment Station  
3909 Halls Ferry Road  
Vicksburg, MS 39180-6199  
  
Dr. J. P. Balsara  
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Mr. J. B. Cheek  
Mr. C. R. Welch  
Mr. J. R. Hossley  
Mr. F. W. Skinner  
Mr. A. E. Jackson  
Dr. J. S. Zelasko  
Mr. J. S. Shore  
Dr. J. H. May  
Mr. J. W. Haskins (Safety and Occupational Health Office)  
Technical Library
2. Applied Research Associates  
Box 120A  
Waterman Road  
South Royalton, VT 05068
3. R&D Associates  
6940 So. Kings Highway  
Suite 210  
Alexandria, VA 22310
4. Defense Nuclear Agency  
Nevada

5. Lachel and Associates  
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Mr. Steve Melzer
7. Commonwealth of Kentucky  
Department of Environmental Protection  
Division of Water Quality  
18 Reilly Road  
Frankfort, KY 40601  
  
Mr. Larry Sowder
8. United States Environmental Protection Agency  
Region IV  
345 Courtland St., NE  
Atlanta, GA 30365  
  
Mr. Arthur G. Linton  
Mr. Darrel R. Hopkins
9. California Research and Technology, Inc.  
5117 Johnson Dr.  
Pleasanton, CA 94588
10. Ft. Knox Military Reservation  
Ft. Knox, KY  
  
DEH: Mr. Don McGar  
Mr. Joe Yates  
G3-Range Division:  
Mr. Andy Andrews
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620 N. Brand Blvd.  
Suite 300  
Glendale, CA 91203  
  
Mr. Joe Valancius  
Mr. John Karagozian

12. Defense Nuclear Agency  
6801 Telegraph Road  
Alexandria, VA 22310-3398

Dr. Paul Senseny  
MAJ Curtis Krieser

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# **Appendix A**

## **Safety and Properties of Pourvex Extra and QM-100**

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This Appendix includes a hazardous substance data sheet and several memoranda and Technical Notes on POURVEX EXTRA and QM-100. As mentioned in the text, POURVEX EXTRA and QM-100 are commercially available, non-cap sensitive blasting agents, which, when properly boosted with sufficient high explosive is detonable. Due to their inherent safety and ease of handling, they have been the explosive chosen for mining and underwater applications. They have been used in quantities of a few pounds to many tons. Included in the usage history is the SIM EVAL test at Silver City, New Mexico.

POURVEX EXTRA and QM-100 have a DOT classification of "Blasting Agent." POURVEX EXTRA and QM-100 are known to be only slightly toxic, and rubber gloves and safety goggles provide adequate personnel protection during normal handling operations. The resistance of POURVEX EXTRA and QM-100 to detonation (even to bullet impact and shock loads of 150 psi), and their relatively low flammability and toxicity, combine to make them safe explosive sources for use in field testing.

**MATERIAL SAFETY DATA SHEET**  
**POURVEX EXTRA**

**Used by Permission**

# EXPLOSIVES

## PRODUCT INFORMATION

Bulletin No. P-29-A

### POURVEX\*™

JANUARY 1989

POURVEX™ is a free flowing, pourable Class B explosive. It is supplied in 5" diameter x 30 lb. bags and 8" diameter x 60 lb. bags. POURVEX™ readily flows to fill the borehole cross-section or to flow around other products used to supplement or increase the borehole loaded density. It is suitable for blasting hard massive rock and is often used as a bottom load to extend drill patterns.

#### PROPERTIES AND SPECIFICATIONS:

Density:	1.33 g/cc
Velocity:	20,000 ft/sec @ 40°F in 5 inch diameter - confined
Fume Class:	Class 1; Acceptable for underground applications
Explosives Classification:	Blasting Agent (packaged) Explosives Class B (bulk shipments)
Shelf Life:	One year from date of manufacture stored at ambient temperature
Water Resistance:	Excellent - minimum 1 week in static water
Packaging:	2 - 5" x 30 lb bags per box 1 - 8" x 60 lb bag per box

#### Priming Requirements:

Only cast boosters are recommended for priming POURVEX™ water gel. A 1 lb HDP cast booster should be used in holes 5" and larger, while the 1/3 lb should be used in holes smaller than 5". POURVEX™ should not be used in holes smaller than 3" in diameter.

A primer is recommended every 10 to 15 ft with a minimum of two primers per hole. For bottom loads, the POURVEX™ charge must contain a primer. If column separation is indicated, additional primers should be used at the discretion of the loader.

Primer placement is accomplished by first loading a foot or two of POURVEX™ then lowering the assembled primer to be followed by the POURVEX™ charge. Additional primers may be added by stringing the primers at the recommended intervals on a detonating cord downline or by placing additional primers with caps down the hole.

(continued over page)

EXPLOSIVES TECHNOLOGIES INTERNATIONAL  
Central and Eastern Region - Canada  
2000 Arden Road, Suite 200, Mississauga, Ontario L4N 5R7 (416) 607-1114  
Central Region - U.S.  
17100 Highway 100, P.O. Box 100, San Diego, CA 92128



EXPLOSIVES  
TECHNOLOGIES

# EXPLOSIVES

## PRODUCT INFORMATION

### POURVEX\*™ (continued)

#### Loading Practices:

Optimum blasting results can be expected when POURVEX™ fills the borehole cross section. This will be realized from bulk loading, but any bagged POURVEX™ should either be shucked at the surface and poured or pumped into the hole, or silt several inches or more before being dropped.

To avoid dilution when bulk product flows through a long water column, it is recommended that holes with more than 30 ft of water should be loaded by pumping with the loading hose lowered to within 20 to 30 ft of the bottom.

Bulk POURVEX™ may tend to mix with the water if the gel structure has been degraded in the pump delivery operation, or if the product must pass through more than approximately 50 ft of loading hose. This problem may be eliminated by lowering the loading hose to the bottom of the hole before pumping begins.

The pumping rate is very important and a rate not exceeding 20 strokes-per-minute is recommended. This translates to a loading rate of about 100 lbs-per-minute.

Stemming material may sink into the POURVEX™ unless a barrier is provided at the POURVEX™/stemming interface. If a charge of cartridge products is to be loaded over the POURVEX™, it should be expected that these cartridges will sink into the POURVEX™.

\*Mfg. by ETI

#### CONTACT YOUR ETI REPRESENTATIVE OR DISTRIBUTOR FOR MORE INFORMATION

Because of the nature of blasting, we cannot anticipate all conditions under which this information and ETI products, or other products in combination with ETI products may be used and therefore we will not accept any responsibility for results or for direct, indirect, special or consequential damages. All users are advised to make their own tests to determine the safety and suitability of each such product or product combination for their own purposes. Unless otherwise agreed in writing, we sell the products without warranty, and buyers and users assume all responsibility and liability for loss or damage arising from the handling and use of our products, whether used alone or in combination with other products.

ETI 122588

EXPLOSIVES TECHNOLOGIES INTERNATIONAL  
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Central Region - U.S.





EXPLOSIVES  
TECHNOLOGIES  
INTERNATIONAL

## MATERIAL SAFETY DATA SHEET

MSDS NO. 2  
PAGE 1 OF 6

### SECTION 1 - PRODUCT IDENTIFICATION

NAME: WATER GEL PRODUCTS  
GRADE: PROPELLANT - CLASS B  
TRADE NAMES AND SYNONYMS: POURVEX® P EXTRA BULK ###

### = NUMBER, NAME AND/OR LETTER DESIGNATION FOR PRODUCTS

MANUFACTURER/DISTRIBUTOR: EXPLOSIVES TECHNOLOGIES INTERNATIONAL  
ROCKWOOD OFFICE PARK, BLDG. 1  
501 CARR ROAD  
WILMINGTON, DE 19809

EXPLOSIVES TECHNOLOGIES INTERNATIONAL  
PLAZA 5, SUITE 200  
2000 ARGENTIA ROAD  
MISSISSAUGA, ONTARIO L5N 2R7

PRODUCT INFORMATION PHONE:	USA	CANADA
	(800) 255-8384	(416) 567-2250
TRANSPORTATION EMERGENCY PHONE:	(800) 424-9300	(705) 472-1300

### SECTION 2 - HAZARDOUS COMPONENTS

CHEMICAL	CAS NUMBER
AMMONIUM NITRATE	6484-52-2
MONOMETHYLAMINE NITRATE	22113-87-7
CALCIUM NITRATE	10124-37-5
SODIUM NITRATE	7631-99-4
ALUMINUM	7429-90-5
CARBONACEOUS FUEL	NONE
PERLITE	12736-96-8
SILICA	65997-17-3
OIL	NONE
ETHYLENE GLYCOL	107-21-1

NAME: WATER GEL PRODUCTS (BLASTING AGENTS) - NON-CAP SENSITIVE

SECTION 3 - TOXIC CHEMICALS NOTIFICATION PER 40 CFR 372

PACKAGED WATER GEL PRODUCTS ARE EXEMPTED FROM TOXIC CHEMICAL REPORTING SINCE THEY MEET THE DEFINITION OF AN "ARTICLE". BULK WATER GEL PRODUCTS MAY CONTAIN THE FOLLOWING TOXIC CHEMICALS:

CHEMICAL	CAS NUMBER	%
AMMONIUM NITRATE SOLUTION	6484-52-2	44.0 (MAX)
ETHYLENE GLYCOL	107-21-1	2.0 (MAX)

SECTION 4 - PHYSICAL DATA

SPECIFIC GRAVITY:	1.1-1.4
FORM:	FLUID GEL
POURVAN 100:	GRANULAR
ALL OTHERS:	RUBBER-LIKE GEL
PACKAGE:	PLASTIC BAGS, TUBES OR BULK
COLOR:	WHITE TO GRAY

SECTION 5 - HAZARDOUS REACTIVITY

INSTABILITY: UNSTABLE WITH HEAT. UNSTABLE WITH SHOCK.

INCOMPATIBILITY: INCOMPATIBLE WITH ACIDS, ALKALIES, OXIDANTS.

DECOMPOSITION: DECOMPOSES WITH HEAT. DECOMPOSES WITH SHOCK. DECOMPOSES BY REACTION WITH ACIDS, ALKALIES, OXIDANTS. HAZARDOUS GASES PRODUCED ARE NITROGEN OXIDES, SILICA AND ALUMINA FUMES.

POLYMERIZATION: POLYMERIZATION WILL NOT OCCUR.

SECTION 6 - FIRE AND EXPLOSION DATA

**FIRE AND EXPLOSION HAZARDS**

WILL DETONATE IF SUITABLY PRIMED, WITH SEVERE IMPACT, OR BY HEAT OR FLAME.  
HAZARDOUS GASES PRODUCED IN FIRE ARE NITROGEN OXIDES, SILICA AND ALUMINA FUMES.  
DOT CLASSIFICATION: BLASTING AGENT, N.O.S.

**EXTINGUISHING MEDIA**

NONE

**SPECIAL FIRE FIGHTING INSTRUCTIONS**

DO NOT FIGHT FIRE. KEEP PERSONNEL REMOVED AND UPWIND OF FIRE. ISOLATE AREA.  
EVACUATE PERSONNEL TO A SAFE AREA.



NAME: WATER GEL PRODUCTS (BLASTING AGENTS) - NON-CAP SENSITIVE

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**SECTION 7 - HEALTH HAZARD INFORMATION**

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**PRINCIPAL HEALTH HAZARDS**

THESE PRODUCTS ARE MIXTURES AND HAVE NOT BEEN TESTED FOR TOXICITY. DETONATION MAY CAUSE SEVERE PHYSICAL INJURY, INCLUDING DEATH. OVEREXPOSURE TO THE PRODUCTS BY INHALATION, EYE OR SKIN CONTACT OR INGESTION MAY CAUSE THE HEALTH EFFECTS DESCRIBED BELOW FOR COMPONENTS.

**AMMONIUM NITRATE**

ORAL LD50: 3,732 mg/kg IN RATS

AMMONIUM NITRATE IS A SKIN AND EYE IRRITANT. TOXIC EFFECTS IN ANIMALS FROM ACUTE EXPOSURE BY INGESTION INCLUDE NEUROLOGICAL EFFECTS AND NONSPECIFIC EFFECTS SUCH AS WEIGHT LOSS AND IRRITATION.

HUMAN HEALTH EFFECTS FROM OVEREXPOSURE BY SKIN OR EYE CONTACT OR INGESTION MAY INITIALLY INCLUDE SKIN IRRITATION WITH DISCOMFORT OR RASH AND EYE IRRITATION WITH DISCOMFORT, TEARING OR BLURRING OF VISION.

**MONOMETHYLAMINE NITRATE**

SKIN ABSORPTION LD50: GREATER THAN 11,000 MG/KG IN RABBITS

ORAL AID: 5,000 MG/KG IN RATS

MONOMETHYLAMINE NITRATE IS A SKIN AND EYE IRRITANT. TOXIC EFFECTS DESCRIBED IN ANIMALS FROM EXPOSURE BY INHALATION INGESTION, OR SKIN CONTACT INCLUDE METHEMGLOBINEMIA, LIVER EFFECTS, AND NONSPECIFIC EFFECTS SUCH AS WEIGHT LOSS AND IRRITATION.

HUMAN HEALTH EFFECTS OF OVEREXPOSURE BY INHALATION, INGESTION, OR SKIN OR EYE CONTACT MAY INITIALLY INCLUDE SKIN IRRITATION WITH DISCOMFORT OR RASH AND EYE IRRITATION WITH DISCOMFORT, TEARING, OR BLURRING OF VISION.

**CALCIUM NITRATE**

REPORTED HUMAN HEALTH EFFECTS FROM OVEREXPOSURE INCLUDE IRRITATION AND CAUTERIZING ACTION OF SKIN AND MUCCOUS MEMBRANES, GASTRIC IRRITATION AND CYANOSIS.

**SODIUM NITRATE**

ORAL LD50: 3,000 mg/kg IN RATS

IN ANIMAL TESTS SODIUM NITRATE WAS AN EYE IRRITANT. IT WAS NOT MUTAGENIC IN BACTERIAL CELL CULTURES BUT HAS SHOWN REPRODUCTIVE EFFECTS. TOXIC EFFECTS IN ANIMALS FROM EXPOSURE BY INGESTION INCLUDE ABDOMINAL PAIN, DIARRHEA, MUSCULAR WEAKNESS, CONVULSIONS, CYANOSIS AND DEATH. REPORTED HUMAN HEALTH EFFECTS INCLUDE NAUSEA, VOMITING, CRAMPS, HEADACHES AND CONVULSIONS.

NAME: WATER GEL PRODUCTS (BLASTING AGENTS) - NON-CAP SENSITIVE

SECTION 7 - HEALTH HAZARD INFORMATION (CONTD.)

**ALUMINUM POWDER**

TOXIC EFFECTS DESCRIBED IN ANIMALS FROM SHORT EXPOSURES TO ALUMINUM POWDER BY INHALATION INCLUDE PULMONARY EFFECTS. HUMAN HEALTH EFFECTS FROM OVEREXPOSURE BY INHALATION, INGESTION, OR SKIN OR EYE CONTACT MAY INITIALLY INCLUDE TEMPORARY LUNG IRRITATION EFFECTS WITH COUGH, DISCOMFORT, DIFFICULTY BREATHING, OR SHORTNESS OF BREATH. CHRONIC AND EXCESSIVE EXPOSURES MAY LEAD TO CHRONIC LUNG DISORDERS WITH SYMPTOMS OF LUNG INSUFFICIENCY. INDIVIDUALS WITH PREEXISTING DISEASES OF THE LUNGS MAY HAVE INCREASED SUSCEPTIBILITY TO THE TOXICITY OF EXCESSIVE EXPOSURES.

**OTHER HEALTH HAZARDS**

**OIL (NO. 2 FUEL OIL)**

THIS MATERIALS IS A SKIN IRRITANT. TOXIC EFFECTS DESCRIBED IN ANIMALS FROM EXPOSURE BY INHALATION INCLUDE LIVER AND KIDNEY EFFECTS. IN A LIFETIME SKIN PAINTING STUDY IN MICE NO. 2 BURNER FUEL REPORTEDLY SHOWED WEAK CARCINOGENIC ACTIVITY. TESTS FOR MUTAGENIC ACTIVITY IN BACTERIAL AND MAMMALIAN CELL CULTURES HAVE BEEN INCONCLUSIVE. HUMAN HEALTH EFFECTS FROM OVEREXPOSURE BY INHALATION, EYE OR SKIN CONTACT OR INGESTION MAY INITIALLY INCLUDE SKIN IRRITATION WITH DISCOMFORT OR RASH AND EYE IRRITATION WITH DISCOMFORT, TEARING OR BLURRING OF VISION.

**ETHYLENE GLYCOL**

IN ANIMAL TESTS ETHYLENE GLYCOL IS AN EYE IRRITANT. TOXIC EFFECTS IN ANIMALS FROM EXPOSURE BY INHALATION, EYE OR SKIN CONTACT OR INGESTION INCLUDE KIDNEY AND LIVER EFFECTS. REPORTED HUMAN HEALTH EFFECTS FROM OVEREXPOSURE BY INHALATION, EYE OR SKIN CONTACT OR INGESTION INCLUDE NAUSEA, HEADACHE, WEAKNESS, LOSS OF KIDNEY FUNCTION, EDEMA, UREMIA, TEMPORARY NERVOUS SYSTEM DEPRESSION AND ANAESTHETIC EFFECTS.

**SILICA**

OVEREXPOSURE TO CERTAIN FORMS OF SILICA BY INHALATION CAUSES SILICOSIS.

**NITROGEN OXIDE FUMES FROM DETONATION**

NITROGEN OXIDES ARE SKIN, EYE AND RESPIRATORY SYSTEM IRRITANTS. SYSTEMIC TOXICITY RESULTING FROM OXIDATION OF LUNG TISSUE INCLUDES EMPHYSEMA, BRONCHITIS AND BRONCHOPNEUMONIA. ACUTE EXPOSURE CAN LEAD TO DEATH FROM ASPHYXIA OR PULMONARY EDEMA. IN ANIMALS, NITROGEN OXIDE CAUSED METHEMOGLOBINEMIA, WAS NOT CARCINOGENIC, BUT CAUSED EMBRYOTOXICITY AND REPRODUCTIVE EFFECTS.

**CARCINOGENICITY**

NONE OF THE COMPONENT(S) OF THIS MATERIAL IS LISTED AS A CARCINOGEN BY NTP, IARC, OR OSHA.

NAME: WATER GEL PRODUCTS (BLASTING AGENTS) - NON-CAP SENSITIVE

SECTION 7 - HEALTH HAZARD INFORMATION (CONTD.)

EXPOSURE LIMITS

"TLV" (ACGIH):	NONE ESTABLISHED
PEL (OSHA):	NONE ESTABLISHED
AMMONIUM NITRATE:	NONE ESTABLISHED
SILICA:	"TLV" (ACGIH) 0.1 mg/M3 RESPIRABLE DUST
ALUMINUM POWDER:	"TLV" (ACGIH) 10 mg/M3
ETHYLENE GLYCOL:	"TLV" (ACGIH) C 50 ppm

SAFETY PRECAUTIONS

AVOID BREATHING VAPORS OR MIST. AVOID CONTACT WITH EYES. AVOID CONTACT WITH SKIN. AVOID CONTACT WITH CLOTHING, WASH THOROUGHLY AFTER HANDLING. WASH CLOTHING AFTER USE.

FIRST AID

INHALATION

NOT A LIKELY ROUTE OF EXPOSURE.

SKIN CONTACT

FLUSH SKIN WITH WATER

NOTE: IF DETONATION CAUSES PHYSICAL INJURY, GET MEDICAL ATTENTION IMMEDIATELY. IF DETONATION FUMES ARE INHALED, REMOVE TO FRESH AIR. IF NOT BREATHING, GIVE ARTIFICIAL RESPIRATION, PREFERABLY MOUTH-TO-MOUTH. IF BREATHING IS DIFFICULT, GIVE OXYGEN. CALL A PHYSICIAN.

EYE CONTACT

IN CASE OF CONTACT, IMMEDIATELY FLUSH EYES WITH PLENTY OF WATER FOR AT LEAST 15 MINUTES. CALL A PHYSICIAN.

INGESTION

IF SWALLOWED, INDUCE VOMITING IMMEDIATELY BY GIVING TWO GLASSES OF WATER AND STICKING FINGER DOWN THROAT. NEVER GIVE ANYTHING BY MOUTH TO AN UNCONSCIOUS PERSON. CALL A PHYSICIAN.

SECTION 8 - PROTECTION INFORMATION

GENERALLY APPLICABLE CONTROL MEASURES AND PRECAUTIONS

USE ONLY WITH ADEQUATE VENTILATION. KEEP AWAY FROM HEAT, SPARKS AND FLAMES. KEEP CONTAINER IN A COOL PLACE. DO NOT MIX WITH ACIDS, ALKALIES, OXIDANTS. CONSULT DD'S AND DON'TS ON CASE INSERT SUPPLIED WITH PRODUCT. DO NOT CONSUME FOOD, DRINK OR TOBACCO IN AREAS WHERE THEY MAY BECOME CONTAMINATED WITH THIS MATERIAL.

PERSONAL PROTECTIVE EQUIPMENT

COVERALL CHEMICAL SPLASH GOGGLES IF EYE CONTACT IS LIKELY. PROTECTIVE CLOTHING IF SPLASH IS LIKELY. IMPERVIOUS GLOVES SUCH AS NEOPRENE IF CONTACT WITH PRODUCT IS LIKELY.

NAME: WATER GEL PRODUCTS (BLASTING AGENTS) - NON-CAP SENSITIVE

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**SPILL, LEAK OR RELEASE**

REVIEW FIRE AND EXPLOSION HAZARDS AND SAFETY PRECAUTIONS BEFORE PROCEEDING WITH CLEAN UP. USE APPROPRIATE PROTECTIVE EQUIPMENT DURING CLEAN UP.

DIKE SPILL. PREVENT LIQUID FROM ENTERING SEWERS, WATER WAYS OR LOW AREAS. DO NOT USE DAMAGED OR WET MATERIAL. CONTROL ACCESS TO AREA AND REMOVE SOURCES OF HEAT OR IMPACT. PICK UP BY HAND FOR DISPOSAL USING NON-SPARKING TOOLS. DO NOT USE POWER EQUIPMENT.

**WASTE DISPOSAL**

DO NOT BURN. CONSULT AN EXPLOSIVES MANUFACTURER FOR RECOMMENDED METHODS OF DESTROYING EXPLOSIVE MATERIALS. COMPLY WITH APPLICABLE FEDERAL REGULATIONS UNDER THE AUTHORITY OF THE RESOURCE CONSERVATION AND RECOVERY ACT (40 CFR, PARTS 260-271). DO NOT FLUSH TO SURFACE WATER OR SANITARY SEWER SYSTEM.

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**SECTION 9 - SHIPPING AND STORAGE INFORMATION**

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**SHIPPING INFORMATION - USA**

SHIPPING INFORMATION DEPENDS ON PACKAGING AND PRODUCT CHARACTERISTICS. CHECK MANUFACTURER OR SHIPPER FOR SPECIFIC INFORMATION.

**STORAGE CONDITIONS**

STORE IN WELL VENTILATED AREA. STORE IN COOL PLACE. DO NOT STORE WITH OTHER EXPLOSIVES. STORE IN ACCORDANCE WITH NATIONAL FIRE PROTECTION ASSOCIATION REGULATION. STORE IN ACCORDANCE WITH FEDERAL REGULATIONS. DO NOT STORE OR CONSUME FOOD, DRINK OR TOBACCO IN AREAS WHERE THEY MAY BECOME CONTAMINATED WITH THIS MATERIAL. STORE IN APPROVED TYPE MAGAZINE.

**SHIPPING AND STORAGE INFORMATION - CANADA**

TRANSPORT AND STORE ACCORDING TO CTC AND EXPLOSIVES ACT. ALSO REFER TO TRANSPORT CANADA'S PUBLICATION "EMERGENCY RESPONSE GUIDE TO DANGEROUS GOODS".

SHIPPING NAME:	EXPLOSIVE, BLASTING, TYPE E
CLASSIFICATION:	1.5D
UN NO.:	0332
DATE OF LATEST REVISION:	1/90
PERSON RESPONSIBLE FOR MSD	TECHNICAL SERVICES MANAGER
ADDRESS:	EXPLOSIVES TECHNOLOGIES INTERNATIONAL ROCKWOOD OFFICE PARK, BLDG. 1 501 CARR ROAD WILMINGTON, DE 19809

WATERGEL.MSD  
AJM

EXPLOSIVES TECHNOLOGIES INTERNATIONAL INC.  
Rockwood Office Park, Bldg. 1  
501 Cary Road  
Wilmington, DE 19809

MATERIAL SAFETY DATA SHEET

**PREVENTION OF ACCIDENTS IN THE USE OF EXPLOSIVES**

THE PREVENTION OF ACCIDENTS IN THE USE OF EXPLOSIVES IS A RESULT OF CAREFUL PLANNING AND OBSERVANCE OF THE BEST KNOWN PRACTICES. THE EXPLOSIVES USER MUST REMEMBER THAT HE IS DEALING WITH A POWERFUL FORCE AND THAT VARIOUS DEVICES AND METHODS HAVE BEEN DEVELOPED TO ASSIST HIM IN DIRECTING THIS FORCE. HE SHOULD REALIZE THAT THIS FORCE, IF MISDIRECTED, MAY EITHER KILL OR INJURE BOTH HIM AND HIS FELLOW WORKERS.

**WARNING**

ALL EXPLOSIVES ARE DANGEROUS AND MUST BE CAREFULLY HANDLED AND USED FOLLOWING APPROVED SAFETY PROCEDURES EITHER BY OR UNDER THE DIRECTION OF COMPETENT, EXPERIENCED PERSONS IN ACCORDANCE WITH ALL APPLICABLE FEDERAL, STATE AND LOCAL LAWS, REGULATIONS AND ORDINANCES. IF, AFTER CAREFULLY READING THE ENTIRE LEAFLET(S) "ALWAYS' AND NEVER'S" INSTRUCTIONS AND WARNINGS INSERTED IN EACH CASE OF THESE PRODUCTS, YOU HAVE ANY QUESTIONS OR DOUBTS AS TO HOW TO USE ANY EXPLOSIVE PRODUCTS, DO NOT USE IT BEFORE CONSULTING YOUR SUPERVISOR, OR SUPERVISOR HAS ANY QUESTIONS OR DOUBTS, HE SHOULD CONSULT THE MANUFACTURER BEFORE USE. SEE "ADDITIONAL INFORMATION AND REFERENCES" BELOW.

**ADDITIONAL INFORMATION AND REFERENCES**

IT IS OBVIOUSLY IMPOSSIBLE TO INCLUDE WARNINGS OR APPROVED METHODS FOR EVERY CONCEIVABLE SITUATION. A LIST OF SUGGESTIONS TO AID IN AVOIDING THE MORE COMMON CAUSES OF ACCIDENTS IS SET FORTH IN THE "ALWAYS' AND NEVER'S" INSTRUCTIONS AND WARNINGS INCLUDED A CASE INSERTS WITH THE PRODUCT. ADDITIONAL INFORMATION IS AVAILABLE IN THE BLASTERS' HANDBOOK, PUBLISHED BY E.I. DU PONT DE NEMOURS AND COMPANY, ORDINANCE SAFETY MANUAL, PUBLISHED BY THE U.S. ARMY ORDINANCE DEPARTMENT, AND IN THE INSTITUTE OF MAKERS OF EXPLOSIVES SAFETY LIBRARY PUBLICATIONS LISTED BELOW. COPIES OF THESE TME PUBLICATIONS MAY BE OBTAINED BY WRITING THE INSTITUTE OF MAKERS OF EXPLOSIVES, 1120 NINETEENTH STREET, NORTHWEST, SUITE 310, WASHINGTON, D.C. 20036 OR FROM YOUR EXPLOSIVES SUPPLIER: CONSTRUCTION GUIDE FOR STORAGE MAGAZINES (NO. 1); AMERICAN TABLE OF DISTANCES (NO. 2); SUGGESTED CODE OF REGULATIONS FOR THE MANUFACTURE, TRANSPORTATION, STORAGE, SALE POSSESSION, AND USE OF EXPLOSIVES AND BLASTING MATERIALS (NO. 3); WARNINGS AND INSTRUCTION FOR CONSUMERS IN TRANSPORTING, STORING, HANDLING, AND USING EXPLOSIVE MATERIALS (NO. 4); HANDBOOK FOR THE TRANSPORTATION AND DISTRIBUTION OF EXPLOSIVE MATERIALS (NO. 14); SAFETY GUIDE FOR THE STORAGE, HANDLING AND USE OF EXPLOSIVES MATERIALS (NO. 17); SAFETY GUIDE FOR THE PREVENTION OF RADIO FREQUENCY RADIATION HAZARDS (NO. 20); TME DESTRUCTION OF COMMERCIAL EXPLOSIVES (NO. 21); TME STANDARD FOR THE SAFE TRANSPORTATION OF CLASS C COMMERCIAL DETONATORS (BLASTING CAPS) IN A VEHICLE WITH OTHER CERTAIN EXPLOSIVES (NO. 22).

**MATERIAL SAFETY DATA SHEET**

**QM-100**

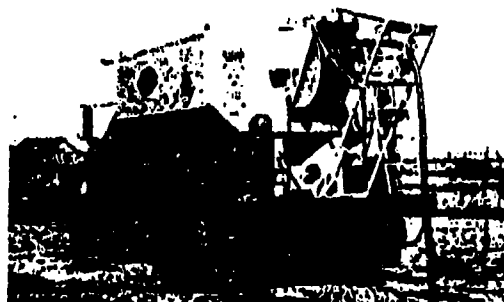
**Used by Permission**

# Technical Information

Eleventh Floor Crossroads Tower Salt Lake City, Utah USA 84144 Telephone: (801) 364-4800 Telex: 38-8353

## RX™ and RX Plus™ Bulk Repumpable Emulsions and ANFO Blends

RX and RX Plus are Bulk Repumpable Emulsion Blasting Agents, which can be used straight or in combinations with up to 30% ANFO. The ANFO containing blends are manufactured in the IRECO RP trucks which have an 11,000 pound capacity tank for the Repumpable Emulsion and a 5,000 pound capacity for pre-mixed ANFO. The two ingredients are mixed, and pumped through a hose into the borehole. Quarrying and construction work are the principle applications for RX and RX Plus.



### Advantages

**Excellent Detonation Properties.** RX and RX Plus with ANFO blends offer a variety of detonation velocities, bulk strengths and all have high gas volumes which combine to give excellent results in nearly all rock formations.

**Bulk Explosives Storage.** The IREGEL REPUMPABLE BULK SYSTEM helps save time and money for mine operators, quarry operators and contractors because it alleviates many explosive storage and handling problems.

**Customer Operated.** RX and RX Plus are logical additions to operations with existing ANFO capabilities. IRECO will provide the equipment, training and technical support necessary to make the system easily operational by customers.

**High Loading Density.** RX and RX Plus Repumpable Explosives and ANFO blends have high borehole loading densities and complete borehole coupling, which result in improved fragmentation and pattern expansion.

### Properties

	Density (lb./cu. ft.) (kg./cu. m.)	Energy (cal./g.) (Joules/g.)	Weight Strength <sup>a</sup>	Bulk <sup>a</sup> Strength <sup>b</sup>	Velocity <sup>a,d</sup> (m./sec.) (ft./sec.)
RX	1.10 1.75	649 220	0.77	1.23	5,200 17,100
RX with 20% ANFO	1.11 1.78	690 225	0.83	1.26	4,800 15,800
RX with 30% ANFO	1.16 1.80	710 200	0.86	1.31	4,600 15,100
RX Plus	1.10 1.75	710 200	0.90	1.33	5,500 17,100
RX Plus with 20%	1.11 1.78	750 205	0.93	1.40	4,800 15,800
RX Plus with 30%	1.16 1.80	710 200	0.94	1.41	4,600 15,100

<sup>a</sup>in ANFO 1.00 is density of 0.82 g./cc. <sup>b</sup>and inch diameter, unconfined

The Explosives Technology Company

800-451-1551

[illegible]

Generally recommended for open pit use however RX and RX Plus can be formulated for underground applications. Consult your IRECO Representative.

Transport, store and handle RX and RX Plus in compliance with Federal, state and local laws governing bulk Blasting Agents.

IRECO disclaims any warranties with respect to this product, the safety or suitability thereof, or the results to be obtained, whether express or implied, INCLUDING WITHOUT LIMITATION, ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE AND/OR ANY OTHER WARRANTY. Buyers and users assume all risk, responsibility and liability whatsoever from any and all injuries (including death), losses, or damages to persons or property arising from the use of this product. Under no circumstances shall IRECO be liable for special, consequential or incidental damages or for anticipated profits.

## Appendix A Safety and Properties of POURVEX EXTRA and QM-100





MATERIAL SAFETY DATA SHEET  
IRECO INCORPORATED 11th FL CROSSROADS TOWERS  
SALT LAKE CITY, UTAH 84144  
801-364-4800 TELEX 388111  
FOR 24 HOUR EMERGENCY CALL 800-424-9300

MSDS#1062

DATE: 07-26-90

Supersedes MSDS  
1062 04/25/90

Replaces MSDS  
1003 05/06/88  
1050 11/06/87  
1064 08/01/87  
1065 05/06/88

### SECTION I - PRODUCT IDENTIFICATION

Trade Name: IREGEL Bulk Series

Chemical Name: Mixture

Synonyms: 1115, 1116, 1116D, 1116P, 1116R, 1117, 1126, 1126P, 1136, 1136A, 1136G, 1136P, 1136PS, 1137, 1146P, 1176, 1177, 1207, 1237, 1256, HD, HD-1, HD-2, HD-3, HD-4, HD-5, HD-6, HD-7, HD-8, HD-A, HD-B, HD-C, HD-D, HD-E, HD-F, HD-G, HD-H, HD-I, HD-J, RD-1, RD-2, RD-3, RD-4, RD-5, RD-6, RG-1, RG-2, RG-3, RG-3, RG-6, RG-12, RG-20, RG-30, RP, RP-HD, RX, RX-HD, RX Plus, RU, IREMITE 220, IREMEX 664, IREGEL 762, 764, RD1ND, IREGEL 362P, IREGEL RA

Product Appearance & Odor: White or pink opaque semi-solid which will appear gray if product contains aluminum.  
Slight fuel oil odor.

DOT Hazard Class: Blasting Agent  
Shipped or delivered as Bulk Products

### SECTION II - HAZARDOUS INGREDIENTS

Ingredients:	CAS#	% (Range)	TLV
Ammonium Nitrate	6484-52-12	30-80	No Value Established
*Thiourea	62-56-6	0.0-0.3	No Value Established
*Aluminum	7429-90-5	0.0-10.00	10 mg/m <sup>3</sup> (ACGIH)

\*The above hazardous ingredients are not found in the majority of listed IREGEL products.

Ingredients, other than those mentioned above, as used in this product are not hazardous as defined under current Department of Labor regulations.

### SECTION III - PHYSICAL DATA

Boiling Point: (C°) (F°) N/A	Vapor Pressure: (mm Hg) N/A
Vapor Density: (Air = 1) N/A	Specific Gravity: 0.95-1.45 (g/cc)
Percent Volatile by Volume: N/A	Solubility in Water: Product partially dissolves very slowly in water.

Evaporation Rate (Butyl Acetate = 1): N/A

#### SECTION IV - FIRE AND EXPLOSION HAZARD DATA

MSDS#1062

07/26/90

Page 2 of 3



Flash Point:  $>80^{\circ}\text{C}$

Flammable Limits: No Limits Established

Extinguishing Media: (See Special Fire Fighting Procedures Section)

Special Fire Fighting Procedures: Do not attempt to fight fires involving explosive materials. Evacuate all personnel to predetermined safe location.

Unusual Fire and Explosion Hazards: Blasting Agents can explode under fire conditions. Burning materials may produce toxic vapors.

#### SECTION V - HEALTH HAZARD DATA

##### Effects of Overexposure

Eyes: Can cause irritation, redness and tearing.

Skin: Prolonged contact may cause irritation.

Ingestion: Large amounts may be harmful if swallowed.

Inhalation: May cause dizziness, nausea, intestinal upset.

Systemic or other effects: Thiourea is a suspected carcinogen (in animals).

##### Emergency and First Aid Procedures

Eyes: Irrigate with running water for at least 15 minutes.  
If irritation persists, seek medical attention.

Skin: Wash with soap and water.

Ingestion: Induce vomiting. Seek medical attention.

Inhalation: Remove to fresh air.

Special Considerations: N/A

#### SECTION VI - REACTIVITY DATA

Stability: Stable under normal conditions, may explode when subjected to fire or super-sonic shock especially when confined or in large quantity.

Conditions to Avoid: Protect from heat, sparks and open flame.

Materials to Avoid (Incompatibility): Strong acids and strong alkali.

Hazardous Decomposition Products:  $\text{NO}_x$ , CO

Hazardous Polymerization: N/A      Conditions to Avoid: N/A

## SECTION VII - SPILL OR LEAK PROCEDURES

MSDS#1062  
07/26/90  
Page 3 of 3



Steps to be taken in Case Material is Released or Spilled: Dike or otherwise contain in spill area. Protect from heat, sparks and open flame.

Waste Disposal Method: Dispose of in accordance with Federal, State and local regulations.

## SECTION VIII - SPECIAL PROTECTION INFORMATION

Ventilation: General room ventilation is normally adequate.

Respiratory Protection: None normally required.

Protective Clothing: Gloves and work clothing which reduce skin contact are suggested.

Eye Protection: Safety glasses and/or face shield is suggested.

Other Precautions Required: N/A

## SECTION IX - SPECIAL PRECAUTIONS

Precautions to be taken in handling and storage: Store in compliance with local, State, and Federal regulations.

Other Precautions: Explosive Material. Keep away from heat, sparks and open flame.

## SECTION X - SPECIAL INFORMATION

This product contains the following substances that are subject to the reporting requirements of Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 and 40 CFR Part 372.

<u>Chemical Name</u>	<u>CAS Number</u>	<u>% By Weight</u>
Ammonium Nitrate (in solution)	6484-52-12	30-80
Thiourea	62-56-6	0.0-0.3
Aluminum (fume or dust)	7429-90-5	0.0-10.00

### Disclaimer

The statements contained herein are offered for information purposes only and are intended only for persons having related technical skills. Because conditions and manner of use are outside our control, it is the user's responsibility to determine the conditions of safe use of the product.

## TECHNICAL INFORMATION

**PRODUCT NAME DESCRIPTION:** IREGEL QM 100

**PACKAGING:** Bulk

**USES:** Commercial Mining, Quarrying, Construction

**SAMPLE AVAILABILITY:** Two (2) weeks

**TYPICAL ANALYSIS:** Ammonium Nitrate, Water, Hydrocarbon Oil, Emulsifier, Solid Density Control Agent. The specific formulation is proprietary property of IRECO, Inc. For more information contact IRECO Inc., Salt Lake City, Utah. 801-364-4800.

**PROPERTIES:** 620°C, and atmospheric pressure unless stated otherwise:

Detonation Pressure (kbar):	.....140
Density (gm/cc):	.....1.28 ± .05
Critical Diameter (mm):	.....32
Frictional Sensitivity:	.....No Reaction
Cap Sensitivity:	.....No Reaction
Minimum Booster:	.....2 g cast Pentolite
Detonation Velocity (km/sec):	.....6.2
Total Energy (cal/gm):	.....637
Bulk Strength (cal/cc):	.....815
Viscosity:	.....9,000 cP
Theoretical Maximum Density (gm/cc):	.....1.35
Differential Thermal Analysis (DTA):	.....No Reaction T ≤ 100°C
Thermal Stability (48 hour):	.....Stable
Gap Test (in):	.....1.16, (1.0 - 1.75)
Spark Test:	.....No Reaction
Cratering Ability (TNT=1=1.2ANFO):	.....?
Bullet Impact @ 20°C (30 cal ball):	.....No Reaction
Solid Products (mole/kg):	.....0 - 2
Oxygen Balance (%):	.....0 to -5
Gaseous Products (moles/kg):	.....45
Impact Test:	.....No Reaction
Flammability Test:	.....Burns w/o Det

**HANDLING/STORAGE RESTRICTIONS:** Controlled IAW Federal and Local Regulations.

**STORAGE LIFE:** Six Months

**SPECIAL PRECAUTIONS:**

**COST:** Volume dependent

DOD-4

**DI-L-3311B DOD Explosive Hazard Classification Data Record**

**Data Record No.: 2**

- 1. Nomenclature: IREGEL QM**
- 2. Product Number: QM 100**
- 3. National Stock Number: N/A**
- 4. System subject item is associated with:**  
N/A
- 5. Next higher assembly subject item is associated with:**  
N/A
- 6. Size of unpacked item: Variable: 0.25 to 350 ft<sup>3</sup>**
- 7. Weight of unpacked item: Variable: 50 to 40,000 lbs**
- 8. Explosive or Chemical Formulation:**  
Ammonium Nitrate, Water, Hydrocarbon Oil, Emulsifier, Solid Density Control Agent (microballoons). The specific formulation is proprietary. If more information is required contact: IRECO Inc., Research Department, 3000 West 8600 South, West Jordan, Utah 84088. Telephone Number: 801-364-4800.
- 9. Net Explosives or Chemical Weight: N/A**
- 10. If item contains a liquid or gas, give: N/A**
- 11. Narrative description of the item:**  
Raw Explosive
- 12. Narrative description, step by step, on how the item functions and its relationship to higher assemblies:**  
N/A
- 13. Attached assembly drawings of item plus assembly drawings for explosive components contained in the item:**  
None

**DOD-4**

DI-L-3311B DOD Explosives Hazard Classification Data Record

Product Number: QM 100

DR# 2

Continued

14. Packaging

- a. How item is packed (narrative description):  
Customer Defined and IAW 49 CFR 173.114a(h)
- b. Number of items per inner package: N/A
- c. Number of items per outer package: N/A
- d. DOT number for packing containers (49 CFR):  
49 CFR 173.114a(h)
- e. Gross Weight of packaged items: 5 to 40,000 lbs
- f. Specific DOT labels; if required: Blasting Agent
- g. DOT Special Permit or Exemption:
- h. Drawings of packing and shipping containers: None

15. Special storage and/or shipping limitations, if any:

Storage: Controlled Storage Conditions, 0 ≤ Temperature  
≤ 90°F. Product Life - Six (6) months.

Hazard Classification Data Provided: Yes, Summary Data Sheet

Name: Kevin Hansen

Signature:



IRECO Inc., Salt Lake City, Utah  
801-364-4800

DOD-4

Sponsoring Agency	IRECO	Date	Nov. 22, 1988
Contract Number	None		
PIN, Spec	Batch	Manufacture Date	
QM 100	R8-19-40 #2	Nov. 18, 1988	

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**Detonation Testing\***

	Detonated		Card Gap Test
	Yes	No	50% Value, #Cards
No. 8 EDC, Test 1	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<div style="border: 1px solid black; padding: 2px;">116</div>
Test 2	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
Test 3	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
Test 4	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
Test 5	<input type="checkbox"/>	<input checked="" type="checkbox"/>	

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<u>Ignition and Unconfined Burning Test</u>	Thermal Stability Test 48 hrs at 75°C									
		Average Burn Time (Sec)								
One 2-inch cube	<table style="width: 100%;"> <tr> <td style="width: 15%;">Exploded</td> <td style="width: 15%;">Yes</td> <td style="width: 15%;">No</td> <td style="width: 15%;"></td> </tr> <tr> <td></td> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input checked="" type="checkbox"/></td> <td style="text-align: center;"><div style="border: 1px solid black; padding: 2px;">100</div></td> </tr> </table>	Exploded	Yes	No			<input type="checkbox"/>	<input checked="" type="checkbox"/>	<div style="border: 1px solid black; padding: 2px;">100</div>	Sample Weight Before
Exploded	Yes	No								
	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<div style="border: 1px solid black; padding: 2px;">100</div>							
One 2-inch cube	<table style="width: 100%;"> <tr> <td style="width: 15%;">Exploded</td> <td style="width: 15%;">Yes</td> <td style="width: 15%;">No</td> <td style="width: 15%;"></td> </tr> <tr> <td></td> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input checked="" type="checkbox"/></td> <td style="text-align: center;"><div style="border: 1px solid black; padding: 2px;">93.8</div></td> </tr> </table>	Exploded	Yes	No			<input type="checkbox"/>	<input checked="" type="checkbox"/>	<div style="border: 1px solid black; padding: 2px;">93.8</div>	Sample Weight After
Exploded	Yes	No								
	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<div style="border: 1px solid black; padding: 2px;">93.8</div>							
Four 2-inch cubes	<table style="width: 100%;"> <tr> <td style="width: 15%;">Exploded</td> <td style="width: 15%;">Yes</td> <td style="width: 15%;">No</td> <td style="width: 15%;"></td> </tr> <tr> <td></td> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input checked="" type="checkbox"/></td> <td style="text-align: center;"><div style="border: 1px solid black; padding: 2px;">6.2</div></td> </tr> </table>	Exploded	Yes	No			<input type="checkbox"/>	<input checked="" type="checkbox"/>	<div style="border: 1px solid black; padding: 2px;">6.2</div>	‡ Change in Weight <div style="border: 1px solid black; padding: 2px; width: 100px; margin: 0 auto;">6.2</div>
Exploded	Yes	No								
	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<div style="border: 1px solid black; padding: 2px;">6.2</div>							

Stable, change in weight less than amount of water

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\*Unless otherwise stated, when the samples did not detonate they also failed to react in any manner, burn or decompose.

QM 100

Summary Data Sheet continued

Impact Sensitivity Test

3.75" Drop Test, 10 Trials

10" Drop Test, 10 Trials

Number of Trials Exhibiting --

Number of Trials Exhibiting --

Explosion, Flame, Noise	Decomp Smoke No Noise	No Reaction No Smoke No Noise
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Explosion, Flame, Noise	Decomp Smoke No Noise	No Reaction No Smoke No Noise
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☐0☐0☐10Approval

Test Director

Test Department Head

D. N. Sorenson

D. L. Gordon





# REPORT DOCUMENTATION PAGE

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6. AUTHOR(S) D. W. Murrell and J. S. Shore				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Engineer Waterways Experiment Station 3909 Halls Ferry Road Vicksburg, MS 39180-6199			8. PERFORMING ORGANIZATION REPORT NUMBER Technical Report SL-94-21	
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13. ABSTRACT (Maximum 200 words)  An environmental assessment was necessary to investigate the potential impact of the Underground Technology Program on the environment. The existing test site environment as reviewed, alternatives to the proposed action were considered, and environmental consequences of the proposed action were analyzed. Environmental consequences included effects of construction activities, excavations, and test explosion phenomena on human health and safety, structures, biota, geology, air and water quality, local ecology, socioeconomic factors, and cultural and historical resources. A Finding of No Significant Impact (FONSI) was submitted.				
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